

# **Industrial Processes & The Environment**

**(Handbook No. 4)**

**Textile & Apparel Industry**



**DEPARTMENT OF ENVIRONMENT**  
MINISTRY OF SCIENCE, TECHNOLOGY AND THE ENVIRONMENT, MALAYSIA



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Industrial processes & the environment : (handbook no. 4) textile  
& apparel industry / Department of Environment.

# Industrial Processes & The Environment (Handbook No.4)

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## TEXTILE INDUSTRY

CONTROL NUMBER	0000020157
ACCESSION NUMBER	1000002573
DATE	29-7-2005

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*This handbook has been made possible with the generous support from DANCED,  
the Danish Cooperation for Environment and Development.*

Printed November 2000

# FOREWORD

There is present global recognition that environmental protection demands need not impede industrial growth and expansion, and on the contrary can assure increased business competitiveness; this certainly holds true for industries that adopt the more sensible approach of efficient resource use based on cleaner production technologies. Thus, end-of-pipe solutions should rightfully be left to the last resort. In order for environmental agencies and authorities to be in a position to catalyse industry-adoption of cleaner technologies they have had to initially expand their knowledge-base and keep abreast of the rapid current developments taking place in the field of cleaner industrial production.

The Department of Environment (DOE), in also recognising this need, embarked on the preparation of a series of industry-specific environmental management handbooks within its on-going capacity-building project with support from the Danish Cooperation for Environment and Development (Danced). These handbooks aim at providing DOE Officers with adequate technical knowledge of specific industrial processes and pollution control technologies that would enable them to steer industry towards adoption of more efficient waste management and cleaner production technologies. As an integral part of this effort, the DOE is implementing dialogue/consultation sessions with various groups of individual enterprises. This stems from the realisation that the act of policing should not be the only means to enforce the Environmental Quality Act, 1974, rather it should go hand in hand with a process of consultation with the industries to bring about the desired level of regulatory compliance.

This Handbook on Industrial Processes & The Environment: Textile and Apparel Industry is the fourth handbook in the series of publications. In the course of preparation, extensive discussions have been held with appropriate industry representatives to ensure that the technical information and suggestions presented in the Handbook are both current and of practical value. Through this effort, it is my sincere hope that the future compliance-monitoring activities of the DOE with respect to the textile and apparel industry will be more efficiently performed. It is also our desire that the technical contents will prove beneficial to textile and apparel producers in their endeavour to comply with the environmental regulations and standards through more cost-efficient means.



**Hjh. Rosnani Ibarahim**

Director General of the Environment, Malaysia.

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# GLOSSARY

The following are definitions of the common terms used in this Handbook.

- 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.
- Aerobic** : A biological process active only in the presence of oxygen.
- Anaerobic** : A biological process active only in the absence of free oxygen.
- 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.
- 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.
- 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 "silver".
- 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 to base for acetate fibre.

<b>Cleaner Production</b>	: The continuous application of an integrated preventive strategy to processes and products, in order to reduce environmental risks and impacts.
<b>COD</b>	: Chemical Oxygen Demand. The amount of oxygen required to chemically oxidise organics in a liquid
<b>Combing</b>	: Processing cotton or wool stock through a series of needles (or combs), to remove short fibres and foreign matter.
<b>Direct Dye</b>	: Anionic water-soluble dye used primarily for dyeing full shade ranges on cotton and rayon.
<b>Disperse Dye</b>	: Water-insoluble dye used to colour several synthetic fibres. Applied as a fine dispersion using a carrier
<b>Drawing</b>	: Straightening and paralleling the fibres after combing or carding
<b>End-of-pipe treatment</b>	: Treating pollutants at the end of a process (by, for example, filters, catalysts and scrubbers) instead of preventing their occurrence.
<b>Griege</b>	: Fabrics in unbleached, undyed state prior to finishing. Also referred to as "gray" or "grey" goods.
<b>J-box</b>	: 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.
<b>Jet Dyeing</b>	: A tubular machine utilising water jets to circulate fabric in a dye bath.
<b>Jig</b>	: An open vat which passes full width cloth from a roller through a dye liquor and then on to another roller
<b>Kier</b>	: 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
<b>Knitting</b>	: 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.
<b>Mercerizing</b>	: A process given to cotton yarns and fabric to increase lustre, improve strength and dye ability. Treatment consists of impregnation fabrics with cold concentrated caustic soda solution
<b>Nylon</b>	: 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 linkages are attached to two aromatic links"

<b>Package Dyeing</b>	:	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
<b>Pad</b>	:	A machine for impregnating fabrics with chemicals. It consists essentially of a trough followed by two or more pairs of squeeze rolls
<b>PET</b>	:	Polyethylene terephthalate (polyester)
<b>Polyester</b>	:	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.
<b>Printing</b>	:	Process of producing design 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.
<b>PVA</b>	:	Polyvinyl Alcohol. Synthetic size used in sizing process in cotton fabric manufacturing
<b>Rayon</b>	:	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.
<b>Resin</b>	:	A chemical finish used to impart a property desired in a fabric, such as water repellency etc.
<b>Rope soaper</b>	:	A piece of equipment used for scouring fabrics to remove impurities, processing oils, excess dye etc.
<b>Scouring</b>	:	Removal of foreign components from textiles. Normal scouring materials are alkali (e.g. soda ash) or trisodium phosphate, frequently used in the presence of a surfactant. Textile materials are sometimes scoured by use of a solvent.
<b>Scrubber</b>	:	In air pollution, a device in which a contaminated stream is contacted with a liquid to reduce contaminant emission
<b>Singeing</b>	:	Cloth passes across an open gas flame at a high rate of speed to burn off the loose surface fibres.
<b>Sizing</b>	:	Apply starch, PVA or CMC to warp yarns to minimise abrasion during weaving
<b>Slashing</b>	:	A number of beams from the warper are placed into a creel, run through a size solution and dried on a series of drying >?

<b>Spinning</b>	:	A process by which a large strand of fibers 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.
<b>Sliver</b>	:	A loose ropelike strand into which the sheet of carded fibres is removed through a funnel .
<b>Starch</b>	:	Organic polymer material used as a size; highly biodegradable
<b>Sulfer Dyes</b>	:	A class of dyes which dissolve in aqueous sodium sulfide forming product with a marked affinity for cotton; the dyes are regenerated by air oxidation.
<b>Textured</b>	:	Becked yarns that have greater volume and surface interest than conventional yarn of same fibre.
<b>Texturizing</b>	:	A process used to curl or crimp straight rod-like filament fibres to simulate the appearance, structure, and feel of natural fibres.
<b>Top</b>	:	A continuous untwisted strand or sliver of wool fibres wound into a large ball.
<b>Tufted yarn</b>	:	These are very coarse yarns, usually plied, designed for the tufting trade. Most tufting yarns are made from nylon, acrylic or polyester fibre.
<b>Vat Dye</b>	:	A type of insoluble dye applied from a liquor containing alkali and a powerful reducing agent, generally hydrosulfite. The dye then becomes soluble and completely permeates the cotton fiber. It is then oxidised and again becomes insoluble.
<b>Warp</b>	:	Set of length wise yarns in a loom through which the crosswise filling yarns (weft) are interlaced sometimes called "ends"
<b>Weaving</b>	:	The process of manufacturing fabric by interlacing a series of warp yarns with filling yarns at right angles
<b>Winch</b>	:	See "Beck"
<b>Winding</b>	:	Yarn is wound onto one of several different types of large packages and most of the slubs or thick places are taken out.
<b>Worsted</b>	:	A wool fabric which uses fine grades of wool with finer yarns and higher weaving constructions than a woolen fabric.
<b>Yarn</b>	:	An assemblage of fibres or filaments, either manufactured or natural, twisted or hold together so as to form a continuous strand which can be used in weaving, knitting or otherwise into a textile materials.

# **1.0 ABOUT THIS HANDBOOK**

## **1.1 BACKGROUND**

As part of its capacity-building effort in the area of industrial pollution control, the Department of Environment (DOE) has initiated the preparation of various industry-specific environmental management handbooks. These handbooks, which will contain comprehensive industry process and waste management information, are being developed for major Malaysian industry sectors with relevance to the industrial situation in Malaysia as well as the Malaysian context of environmental management and pollution control.

This Handbook is the 4th in the series entitled Industrial Processes & the Environment. The five(5) industry-specific information handbooks that have been initially identified for preparation are as follows:

- *Industrial Processes & The Environment (Handbook 1):*  
Metal Finishing – Electroplating
- *Industrial Processes & The Environment (Handbook 2):*  
The Raw Natural Rubber Industry
- *Industrial Processes & The Environment (Handbook 3):*  
The Crude Palm Oil Industry
- *Industrial Processes & The Environment (Handbook 4):*  
The Textile Industry
- *Industrial Processes & The Environment (Handbook 5):*  
The Food Industry

The Handbook 1 was published in June 1999, while Handbooks 2 and 3 were published in December 1999.

## **1.2 DEVELOPMENT OF TOOLS FOR ENFORCEMENT**

The DOE Manual on Practical Enforcement earlier prepared, and these series of industry-specific environmental information handbooks, are together aimed at serving the DOE as supporting enforcement tools to enhance the quality and effectiveness of its enforcement activities under the Environmental Quality Act 1974 (EQA). Thus, the Enforcement Manual and the industry-specific handbooks are designed to complement each other in terms of the information which they provide, and as enforcement tools are intended to broaden and strengthen the scope of the Department's enforcement functions and activities.

### 1.3 OBJECTIVES OF THE HANDBOOK

The objectives of this Handbook are to assist DOE Officers to:

- Enhance their knowledge of the Malaysian textile industry, the production processes for textile processing, and cleaner production approaches for more cost-efficient waste management and pollution control;
- Conduct on-site inspections more expeditiously and effectively;
- Disseminate information on cost-efficient waste management technologies, based on pollution prevention and cleaner production approaches.

However, the Handbook may also serve directly as a tool for providing information from DOE to the textile mill owners and operators within the textile industry. In this way it aims to:

- Increase the awareness on environmental issues and potential impacts;
- Change the attitude towards better compliance and housekeeping; and
- Highlight the advantages and opportunities of cleaner production and technologies.

To help accomplish the above objectives, the Handbook specifically provides technical information on;

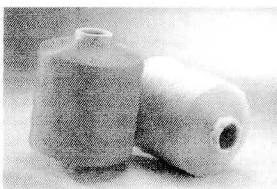
- The textile industry and the manufacturing processes involved;
- Related environmental issues;
- The requirements of the Environmental Quality Act 1974 and subsidiary legislation pertinent to the textile industry;
- The current environmental management practices of the textile industry; and
- Cleaner production approaches and cost-efficient end-of-pipe solutions that can help the textile industry maintain its business competitiveness while meeting the desired environmental objectives and goals.

This Handbook is therefore a source of basic technical information on the Malaysian textile industry, its environmental management issues and current practices, as well as the potential areas of application of cleaner production technologies.

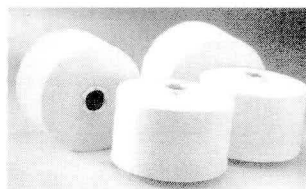
## 1.4 STRUCTURE AND CONTENTS OF THE HANDBOOK

There are nine(9) Sections in this Handbook; the contents of the respective sections are briefly described and presented below:

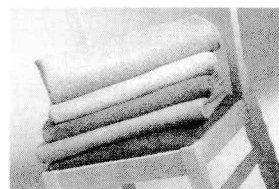
- Section 1:** General information about the Handbook.
- Section 2:** An overview of the textile industry in Malaysia highlighting its economic importance and present status in the Malaysian economy.
- Section 3:** A brief description of the various processes involved in the manufacture of textiles and textile products and an identification of the sources of pollution.
- Section 4:** A highlight of the environmental issues of the textile industry, including a description of the wastes generated and their respective waste characteristics.
- Section 5:** The regulatory framework for environmental control and specific regulatory requirements of importance to the textile industry.
- Section 6:** Pollution control practices of the textile industry. This Section primarily focuses on the available end-of-pipe treatment technologies and air pollution control measures for the textile industry, while only briefly identifying the in-plant waste minimisation and cleaner production technologies.
- Section 7:** This Section focuses on the pollution prevention approach, including waste minimisation and cleaner production technologies.
- Section 8:** Suggested areas of inspection focus, essentially to guide DOE officers on what to look for during an inspection of textile mills to ensure effective enforcement.
- Section 9:** Bibliography.



Nylon textured yarn



Open end yarn



Polyester Knitted Fabric

## 2.0 MALAYSIAN TEXTILE INDUSTRY – AN OVERVIEW

### 2.1 GENERAL PERSPECTIVE

The textile and apparel industry sector is currently a significant contributor to the country's economy and merchandise export. It is one of the major foreign exchange earners and employment generators in Malaysia.

The export and import performance of the Malaysian textile and apparel industry for the past five years from 1994 to 1998 is given in **Table 1**:

**Table 1: Malaysian Exports and Imports of Textiles and Apparel**

Malaysia Exports of Textiles and Apparel, 1994-1998 (in RM millions)					
Year:	1994	1995	1996	1997	1998
Textiles	2,491	3,186	3,677	4,037	4,345
Apparel	5,416	5,681	3,291	3,604	4,176
Malaysia Imports of Textiles and Apparel, 1994-1998 (in RM millions)					
Textiles	4,331	4,758	4,600	4,295	4,210
Apparel	418	397	367	389	346

New developments in the international arena, especially with the establishment of the World Trade Organisation (WTO) and the liberalisation of trade, present both, challenges and opportunities for the Malaysian textile and apparel industry. It is therefore vital for this industry sector to adopt new strategies not only to compete in the new global trade environment but also to take the opportunity of accessing to larger and non-traditional markets other than the present traditional market, such as the USA, EU and Canada. *Tables 2 and 3* show Malaysia's export of textiles and apparel, respectively, to the major importing countries.

The Malaysian textile and apparel industry is gearing itself towards productivity enhancement through emphasis on technology and skilled manpower; merging business operations together and creating industries inter-linkage relationships; emphasis on research and development (R&D) and quality standards to successfully face the intense global competitions. In addition, the industry is also placing greater emphasis on faster delivery, greater customer acquisition, and new designs and product development in meeting the changing need of the global textile and apparel and the apparel trade.

**Table 2: Malaysian Exports of Textiles & Apparel by Major Importing Countries, 1996-1998 (in RM millions)**

Year:	1996	1997	1998
USA	1,656.2	2,875.9	2,871.7
EEC	1,342.8	1,845.6	1,886.9
Canada	663.7	639.1	575.7
Singapore	425.6	522.8	447.3
Australia	135.6	237.2	238.9
Others	2475.4	4,213.1	3,312.3

In line with the government's policy to promote "Buy Made in Malaysia Products", textile and apparel manufacturers are heading towards creation of indigenous brands, upgrading its marketing and distribution capabilities, not only in the domestic market, but also in the international market.

## 2.2 TYPES OF MANUFACTURING ACTIVITIES IN THE TEXTILE INDUSTRY

According to the 1997 Environmental Quality Report, there were 366 textile factories operating in the country and this industrial sector was therefore a significant source of water pollution. The Malaysian textile and apparel industry currently encompasses a broad range of manufacturing activities ranging from polymerisation (production of man-made fibre), spinning, texturing, weaving, knitting, printing, dyeing and finishing, garment-making and industrial textile manufacture, plus other related sectors which include accessories, fishing nets, gloves, bags, hats, chemicals, carpets, and textile machinery.

## 2.3 INTRODUCTION OF ENVIRONMENTAL CONTROL IN THE TEXTILE INDUSTRY

Textile processing generates many waste streams, including water-based effluent as well as air emissions, solid wastes, and hazardous wastes. The nature of the waste generated depends on the type of textile manufacturing facility, the processes and technologies being employed, and the types of fibres and chemicals used.

Comprehensive environmental control of the textile industry commenced soon after the enactment of the Environmental Quality Act, 1974 and the establishment of the Department of Environment (DOE) in 1975. Effluent discharges from the textile industry are regulated by the Environmental

Quality (Sewage and Industrial Effluents) Regulations, 1979 which came into force on January 1<sup>st</sup>, 1979, and the air emissions by the Environmental Quality (Clean Air) Regulations 1978 which came into force on October 1<sup>st</sup>, 1978. Both these regulations were formulated in accordance with powers derived under Section 21 of the Environmental Quality Act, 1974 which provides for the specifying of acceptable conditions of discharge and emissions involving fixed uniform discharge and emission standards. Consultative meetings were held between the Department of Environment and diverse industrial groups and consensus was reached on the establishment of the Standards. A “command and control” or CAC-based enforcement with imposition of penalties and fines for non-compliance was the approach adopted by the DOE.

One of the major problems faced at the time of commencement of enforcement of these regulations was the need for due consideration to be given to existing factories that encountered technical and/or financial constraints in approaching compliance with the regulatory requirements. These factories were given a gestation period of two years to comply with the discharge and emission standards. If for any genuine reason the factories were unable to reach full compliance within the two years, a licence was issued permitting them to contravene the acceptable conditions for an interim period of problem-solving; however, a pollution load-based effluent-related fee was charged for the licence for non-complying discharges into watercourses. New industrial establishments are required to obtain environmental clearance through written permission from the Director-General of Environment at the early planning stage of the project. This is to ensure initially the suitability of the proposed site, and in the later stages the adequacy of the pollution control systems and plans for meeting emission and discharge standards that are imposed with respect to the particular site.

The ultimate disposal of toxic and hazardous wastes that are generated by industry are regulated by the Environmental Quality (Scheduled Wastes) Regulations, 1989, which came into force on 1<sup>st</sup> May 1989.

Based on information provided in the Environmental Quality Report 1997, the textile industry is reported to be relatively insignificant as a source of air pollution. This industry sector had reached a compliance rate of about 83% in relation to the requirements of the Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979. Compliance with the Environmental Quality (Scheduled Wastes) Regulations, 1989 was also found to be satisfactory. The quantity of scheduled wastes contributed by the textile industry in 1997 was reported as 14% of the total generated in the country.

## **3.0 TEXTILE MANUFACTURING PROCESSES AND SOURCES OF POLLUTION**

### **3.1 INTRODUCTION**

Textile manufacturing facilities range from small, family-owned operations using older traditional manufacturing processes to huge integrated mills operating the latest in textile machinery and equipment.

The textile industry comprises a diverse and fragmented group of establishments that produce and/or process textile-related products such as fibre, yarn and fabric for further processing into apparel, home-furnishings and industrial goods. Textile establishments receive and prepare fibres; transform fibres into yarn, thread or webbing; convert the yarn into fabric or related products; dye and finish these materials at various stages of production. The process of converting raw fibres into finished apparel and non-apparel textile products is complex. Thus, most textile mills tend to specialise in producing a specific product or several specific products. Little overlap occurs between knitting and weaving or among production of man-made, cotton, and wool fabrics.

In its broadest sense, the textile industry includes the production of yarn, fabric and finished goods. These stages are highlighted in the process flow chart shown in **Figure 1**.

### **3.2 MANUFACTURING PROCESSES**

#### **3.2.1 Yarn Formation**

Yarn can be produced either from natural or man-made fibres. Natural fibres, known as staple when harvested, include animal and plant fibres, such as cotton and wool. Man-made fibres include:

- (i) Cellulose fibres such as rayon and acetate, which are created by reacting chemicals with wood pulp; and
- (ii) Synthetic fibres, such as polyester and nylon, which are synthesised from organic chemicals.

Textile fibres are converted into yarn by grouping and twisting operations used to bind them together. Although most textile fibres are processed using spinning operations, the processes leading to spinning vary depending on whether the fibres are natural or man-made. Natural fibres, before they can be spun into yarn, must go through a series of preparation steps. Man-made fibres may be processed into filament yarn or staple-length fibres (similar in length to natural fibres) so that they can be spun. Filament yarn may be used directly or following further shaping and texturing. The main steps used for processing natural and man-made fibres into yarn are given below.

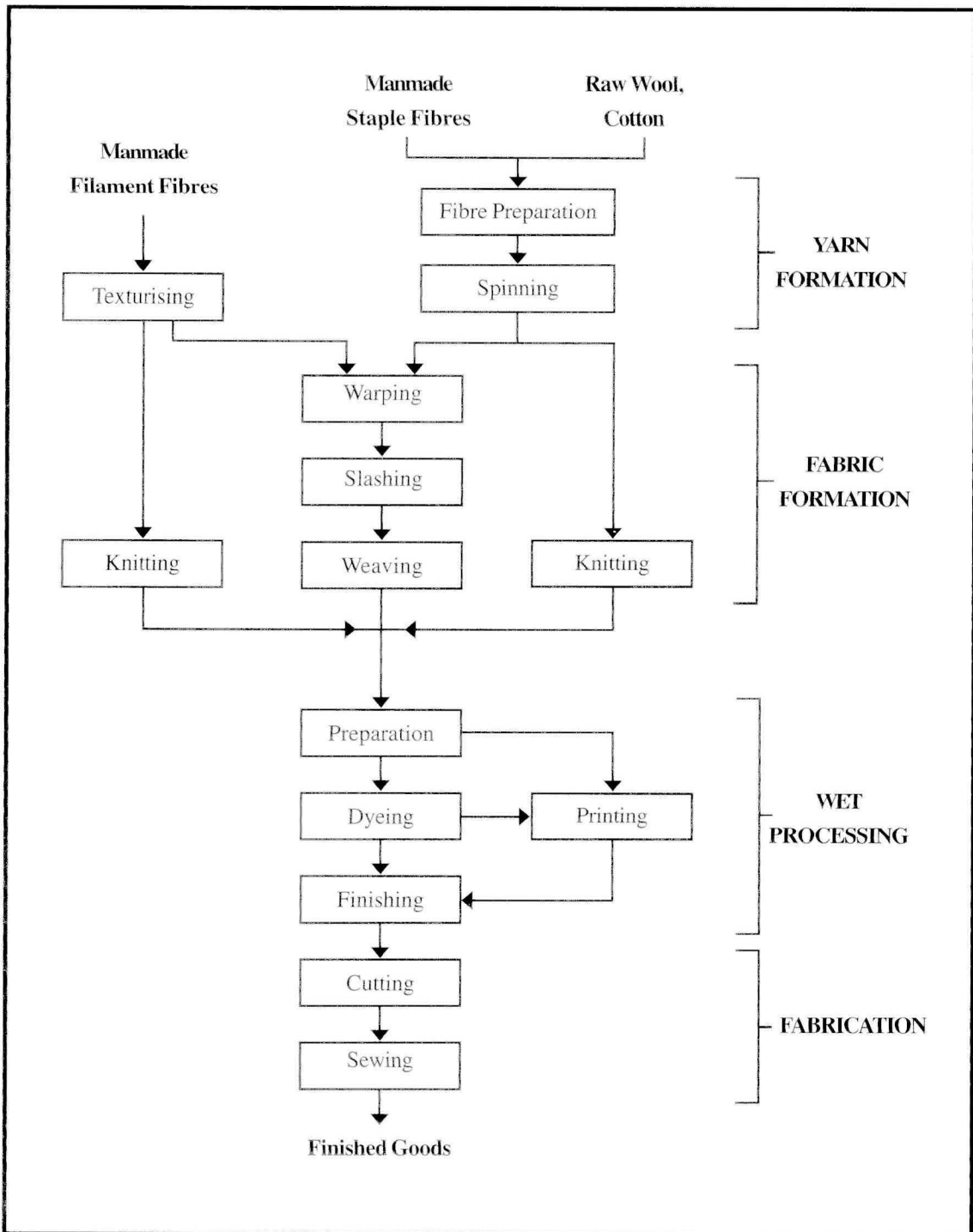


Figure 1: Typical Textile Manufacturing Flow Chart

### 3.2.1.1 Natural Fibres

Natural fibres are first cleaned to remove impurities and are then subjected to a series of brushing and drawing steps designed to soften and align the fibres. The following describes the main steps used for processing cotton and wool.

- *Opening/Blending:*

The compressed bales of fibres are opened to remove particles of dirt, twigs and leaves and blended with fibres from different bales to improve the consistency of the fibre mix. Sorting and cleaning are performed in machines known as openers.

- *Carding:*

Tufts of fibre are conveyed by air stream to a carding machine where the fibres are caused to tease out and align into thin, parallel sheets thus preparing the fibres for spinning. The sheet of carded fibres is removed through a funnel into a loose rope-like strand called a sliver.

- *Combing:*

This is similar to carding except that the brushes and needles are finer and more closely spaced. Several card slivers are fed to the combing machine and removed as a finer, cleaner, and more aligned combed sliver. In the cotton system, the term combed cotton applies to the yarn made from combed sliver.

- *Drawing:*

Several slivers are combined into a continuous, rope-like strand and fed to a machine known as a drawing frame. The drawing frame contains several sets of rollers that rotate at successively faster speeds. As the slivers pass through, they are further drawn out and lengthened to the point where they may be five to six times as long as they were originally. During drawing, slivers from different types of fibres (e.g. cotton and polyester) may be combined to form blends. Once a sliver has been drawn, it is termed a roving.

- Drafting/Roving:

This is a process that uses a frame to stretch the yarn further. This process imparts a slight twist as it removes the yarn and winds it onto a rotating spindle. The yarn, now termed a roving in ring spinning operations, is made up of loose assemblage of fibres drawn into a single strand and is about eight times the length and one-eighth the diameter of the sliver or approximately as wide as a pencil. Following drafting, the rovings may be blended with other fibres before being processed into woven, knitted, or non-woven textiles.

- Spinning:

The fibres are then spun together into either spun yarns or filament yarns. Filament yarns are made from continuous fine strands of man-made fibre (e.g. not staple length fibres). Spun yarns are composed of overlapping staple length fibres that are bound together by twisting. To produce spun yarns, the rovings produced in the drafting step are mounted onto the spinning frame where they are set for spinning. The yarn is first fed through another set of drawing or delivery rollers, which lengthen and stretch it still further. It is then fed onto a high-speed spindle by a yarn guide that travels up and down the spindle. The difference in speed of travel between the guide and the spindle determines the amount of twist imparted to the yarn. The yarn is collected on a bobbin.

There are two methods of spinning, namely, ring spinning or open-end spinning. In ring spinning, the sliver is fed from delivery rollers through a traveller or wire loop, located on a ring. The rotation of the spindle around the ring adds twist to the yarn. In open-end spinning, the sliver passes through rollers into a rotating funnel shaped rotor. The sliver hits the inside of the rotor and rebounds to the left side of the rotor, causing the sliver to twist.

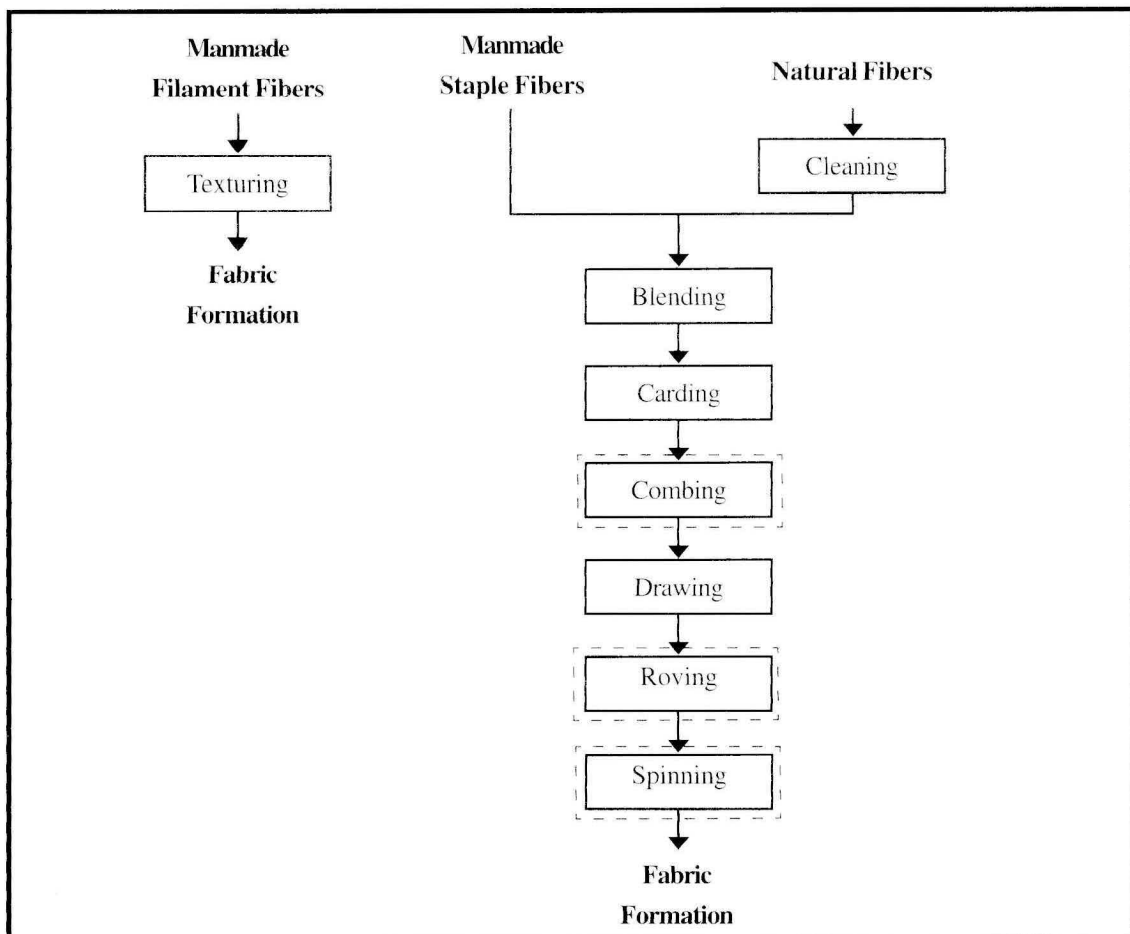
### 3.2.1.2 Manmade Fibres

Since manmade fibres are synthesised from organic chemicals, yarn formation of manmade fibres does not involve the extensive cleaning and combing procedures associated with natural fibres. Manmade fibres, both synthetic and cellulosic, are manufactured using spinning process which involves forming fibres by forcing a liquid through a small opening beyond which the extruded liquid solidifies to form a continuous filament. Following spinning, the manmade fibres are drawn, or stretched to align the polymer molecules and strengthen the filament. Manmade filaments may then be texturised or otherwise treated to simulate physical characteristics of spun natural fibres. Texturising is often used to curl or crimp straight rod-like filament fibres to simulate the appearance, structure, and feel of natural fibres.

Spun yarns are created using manmade fibres that have been cut into staple-length fibres. Staple-length fibres are then used to process fibres on cotton system machinery. Methods for making spun yarn from manmade fibres are similar to those used for natural fibres. Some fibres are processed as tow, or bundles of staple fibres.

Fibres can also be produced as filament yarn, which consists of filament strands twisted together slightly. In mills, filament fibres are wound onto bobbins and placed on a twisting machine to make yarn. Filament yarns may be used directly to make fabric or further twisted to the desired consistency. Manmade filaments often require additional drawing and are processed in an integrated drawing/twisting machine. Manmade filaments are typically texturized using mechanical or chemical treatments to impart characteristics similar to those of yarns made from natural fibres.

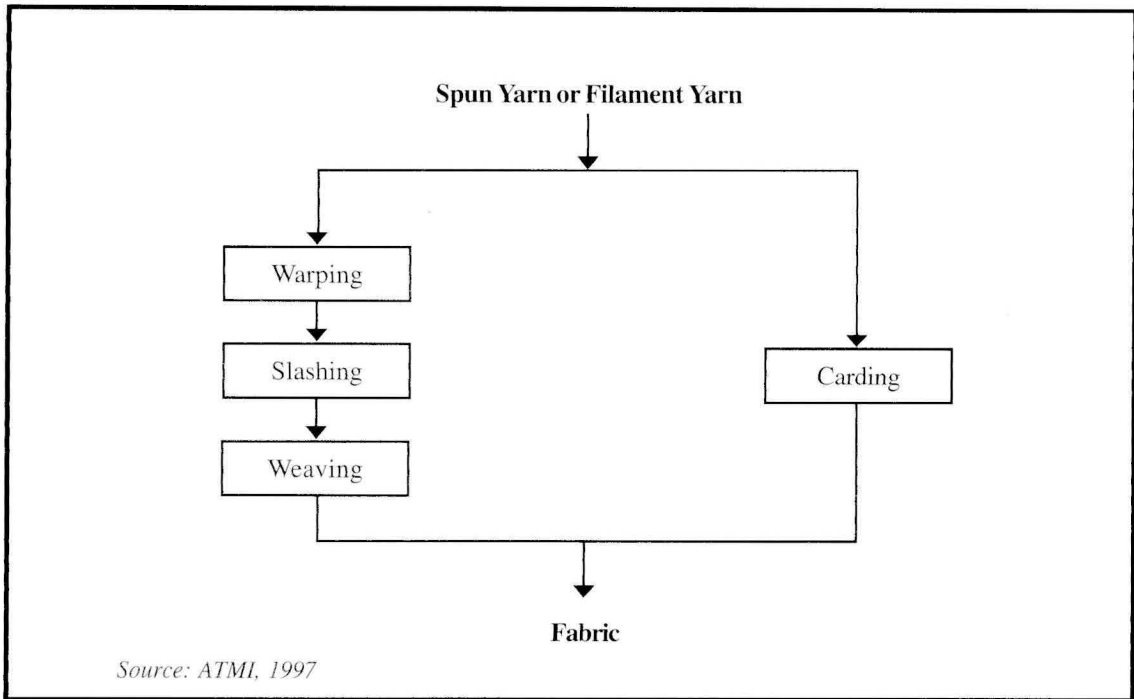
A simplified process flow diagram showing the formation of yarn is shown in **Figure 2**.



**Figure 2: Yarn Formation Processes**

### 3.2.2 Fabric Formation

The major methods for fabric manufacture are weaving and knitting. **Figure 3** shows the fabric formation process for flat fabrics, such as sheets and apparel.



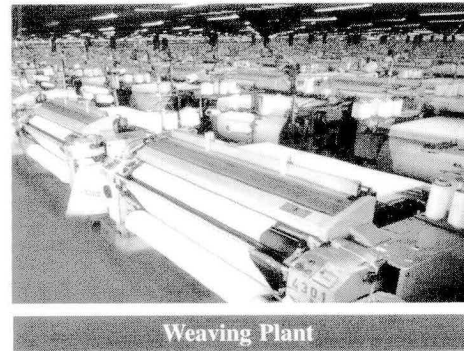
**Figure 3: General Fabric Formation Processes for Producing Flat Fabrics**

Weaving or interlacing of yarns is the most common process used to create fabrics. Weaving mills classified as broadwoven mills consume the largest portion of textile fibre and produce the raw textile material from which most textile products are made. Narrow wovens, non-wovens and rope are also produced primarily for use in industrial applications. Narrow wovens include fabrics less than 30cm (12 inches) in width, and non-wovens include fabrics bonded by mechanical, chemical or other means. Knitting is the second most frequently used method of fabric construction. The popularity of knitting has increased in use due to the increased versatility of techniques, the adaptability of manmade fibres and the growth in consumer demand for wrinkle-resistant, stretchable, snug-fitting fabrics.

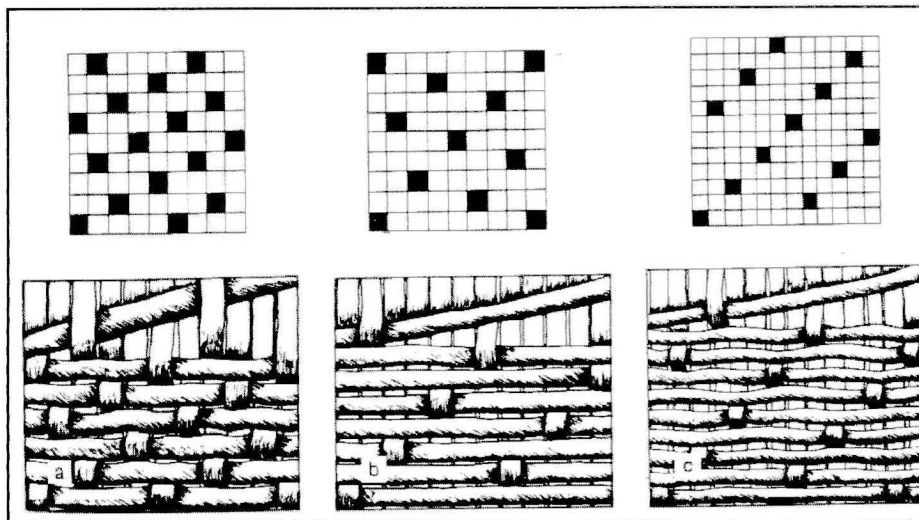
Manufacturers of knit fabrics also consume a sizeable amount of textile fibres. Knit fabrics are generally classified as either weft knit (circular-knit goods) or warp knit (flat-knit goods).

### 3.2.2.1 Weaving

Weaving is performed on modern looms, which contain similar parts and perform similar operations to simple hand-operated looms. Fabrics are formed from weaving by interlacing one set of yarns with another set oriented crosswise. **Figure 4** shows an example of satin weave patterns. Satin, plain, and twill weaves are the most commonly used weave patterns.



In the weaving operation, the length-wise yarns that form the basic structure of the fabric are called the warp and the crosswise yarns are called the filling, also referred to as the weft. While the filling yarns undergo little strain in the weaving process, warp yarns undergo much strain during weaving and must be processed to prepare them to withstand the strain.



Source: B.P. Corbman, *Textile: Fiber to Fabric*, McGraw-Hill, Inc., 1975

**Figure 4: Examples of Satin Weaving Patterns**

Before weaving, warp yarns are first wound on large spools, or cones, which are placed on a rack called a creel. The warp yarns are then unwound and passed through a size solution (sizing/slashing) before being wound onto a warp beam in a process known as beaming. The size solution forms a coating that protects the yarn against snagging or abrasion during weaving. Slashing, or applying size to the warp yarn, uses pad/dry techniques in a large range called a slasher. The slasher is made up of the following: a yarn creel with very precise tension controls; a yarn guidance system; and a sizing delivery system, which usually involves tank storage and piping to the size vessels. The yarn sheet is dipped one or more times in size solution and dried on hot

cans or in an oven. A device called a “lease” is then used to separate yarns from a solid sheet back into individual ends for weaving.

Once size is applied, the wound beam is mounted in a loom. Shuttle looms are rapidly being replaced by shuttleless looms, which have the ability to weave at higher speeds and with less noise. Shuttleless looms are discussed in the next section. The operation of a traditional shuttle loom is discussed in this section to illustrate the weaving process.

The major components of the loom are the warp beam, heddles, harnesses, shuttle, reed, and take-up roll as shown in **Figure 5**. In the loom, yarn processing includes shedding, picking, battening, and taking up operations. These steps are discussed below.

- *Shedding:*

Shedding is the raising of the warp yarns to form a shed through which the filling yarn, carried by the shuttle, can be inserted. The shed is the vertical space between the raised and unraised warp yarns. On the modern loom, simple and intricate shedding operations are performed automatically by the heddle frame, also known as a harness. This is a rectangular frame to which a series of wires, called heddles, are attached. The yarns are passed through the eyeholes of the heddles, which hang vertically from the harnesses.

The weave pattern determines which harness controls which warp yarns, and the number of harnesses used depends on the complexity of the weave.

- *Picking:*

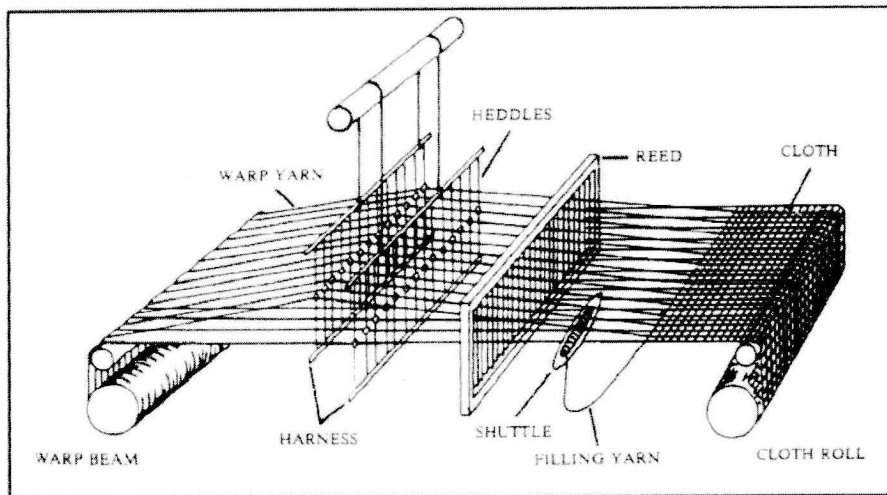
As the harnesses raise the heddles, which raise the warp yarns, the shed is created. The filling yarn is inserted through the shed by a small carrier device called a shuttle. The shuttle is normally pointed at each end to allow passage through the shed. In a traditional shuttle loom, the filling yarn is wound onto a quill, which in turn is mounted in the shuttle. The filling yarn emerges through a hole in the shuttle as it moves across the loom. A single crossing of the shuttle from one side of the loom to the other is known as a pick. As the shuttle moves back and forth across the shed, it weaves an edge, or selvage, on each side of the fabric to prevent the fabric from raveling.

- *Battening:*

As the shuttle moves across the loom laying down the fill yarn, it also passes through openings in another frame called a reed (which resembles a comb). With each picking operation, the reed presses or battens each filling yarn against the portion of the fabric that has already been formed. Conventional shuttle looms can operate at speeds of about 150 to 160 picks per minute.

- *Taking-up and Letting-off:*

With each weaving operation, the newly constructed fabric must be wound on a cloth beam. This process is called taking up. At the same time, the warp yarns must be let off or released from the warp beams.



Source: I.B. Wingate, *Fairchild's dictionary of Textiles*, Fairchild Publications, Inc. 1979

**Figure 5: Typical Shuttle Loom**

- Shuttleless Looms:

Because the shuttle can cause yarns to splinter and catch, several types of shuttleless looms have been developed. These operate at higher speeds and reduced noise levels. Shuttleless looms use different techniques to transport cut pieces of fill yarn across the shed, as opposed to the continuous yarn used in shuttle looms.

Some of the common shuttleless looms include:

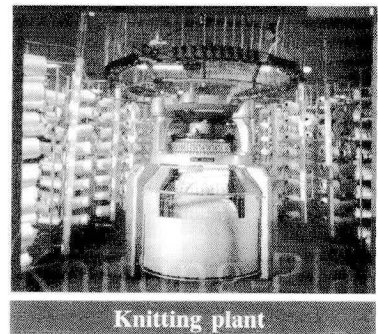
- Water-jet looms
- Air-jet looms
- Rapier looms, and
- Projectile looms

Water-jet looms transport the fill yarn in a high-speed jet of water and can achieve speeds of 400 to 600 picks per minute. Water jets can handle a wide variety of fiber and yarn types and are widely used for apparel fabrics. Air-jet looms use a blast of air to move the fill yarn and can operate at speeds of 800 to 1000 picks per minute. Rapier looms use two thin wire rods to carry the fill yarn and can operate at a speed of 510 picks per minute. Rapiers are used mostly for spun yarns to make cotton and woolen/worsted fabrics. In a double rapier loom, two rods move from each side and meet in the middle. The fill yarn is carried from the rod on the fill side and handed off to the rod on the finish side of the loom. Projectile looms use a projectile to carry the fill yarn across the weave.

Shuttleless looms have been replacing the traditional fly-shuttle loom in recent years. Air looms, although limited in the types of filling yarns they can handle, are increasing in commercial use. The operation of an air jet loom is shown in **Figure 6**. As shown in the figure, yarn is drawn from the yarn package (1) by the measuring wheel and drive roller arrangement (2). Between the yarn package and the measuring wheel is a tube through which an air current flows in opposite direction to the yarn. This maintains a straight even feed of yarn. The yarn then forms a loop (3), which shortens as the pick penetrates further into the shed. The main jet (4) is the major projecting force for the yarn, although supplementary jets (5) are activated to prevent the pick from buckling.

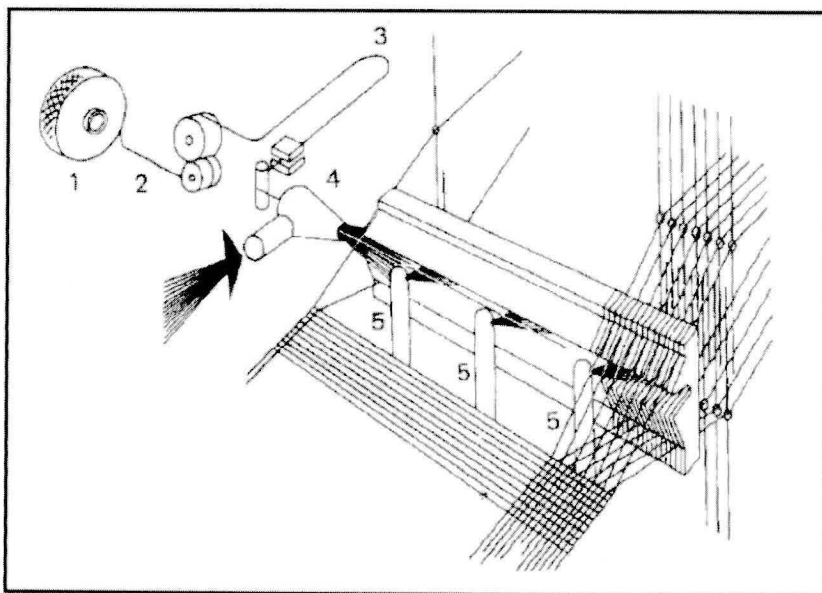
### 3.2.2.2 Knitting

Knitted fabrics may be constructed by using hooked needles to interlock one or more sets of yarns through a set of loops. The loops may be either loosely or closely constructed, depending on the purpose of the fabric. Knitted fabrics can be used for hosiery, underwear, sweaters, slacks, suits, coats, rugs, and other home furnishings. Knitting is performed using either weft or warp processes, depicted in **Figure 7**.



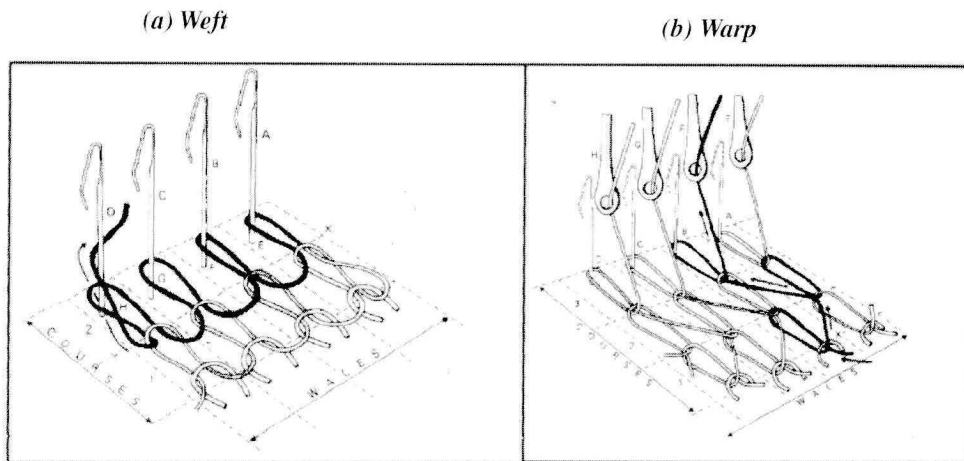
Knitting plant

In weft (or filling) knitting, one yarn is carried back and forth and under needles to form a fabric. Yarns run horizontally in the fabric, and connections between loops are horizontal. In warp knitting, a warp beam is set into the knitting machine. Yarns are interlocked to form the fabric, and the yarns run vertically while the connections are on the diagonal. Several different types of machinery are used in both weft and warp knitting.



Source: A. Ormerod, *Modern Preparation and Weaving machinery*, Butterworths, 1983

**Figure 6:** Typical Air Jet Loom



Source: D.J. Spencer, *Knitting Technology*, Pergamon Press, 1989

**Figure 7: Comparison of Warp and Weft Knitting Methods**

- Warp Knitting:

Warp knitting represents the fastest method of producing fabric from yarns. Warp knitting differs from weft knitting in that each needle loops its own thread. The needles produce parallel rows of loops simultaneously that are interlocked in a zigzag pattern. Fabric is produced in sheet or flat form using one or more sets of warp yarns. The yarns are fed from warp beams to a row of needles extending across the width of the machine (refer **Figure 7 (b)**). Two common types of warp knitting machines are the Tricot and Raschel machines. Raschel machines are useful because they can process all yarn types in all forms (filament, staple, combed, carded, etc.). Warp knitting can also be used to make pile fabrics often used for upholstery.

### 3.2.2.3 Tufting

Tufting is a process used to create carpets, blankets, and upholstery. Tufting is done by inserting additional yarns into a ground fabric of desired weight and yarn content to create a pile fabric. The substrate fabric can range from a thin backing to heavy burlap-type material and may be woven, knitted, or web. In modern tufting machines, a set of hollow needles carries the yarn from a series of spools held in a creel and inserts the yarn through the substrate cloth. As each needle penetrates the cloth, a hook on the underside forms a loop by catching and holding the yarn. The needle is withdrawn and moves forward, much like a sewing machine needle. Patterns may be formed by varying the height of the tuft loops. To make cut-loop pile, a knife is attached to the hook and the loops are cut as the needles are retracted. Well over 90 percent of broadloom carpeting is made by tufting, and modern machines can stitch at rates of over 800 stitches per minute, producing some 650 square yards of broadloom per hour.

### 3.2.3 Wet Processing

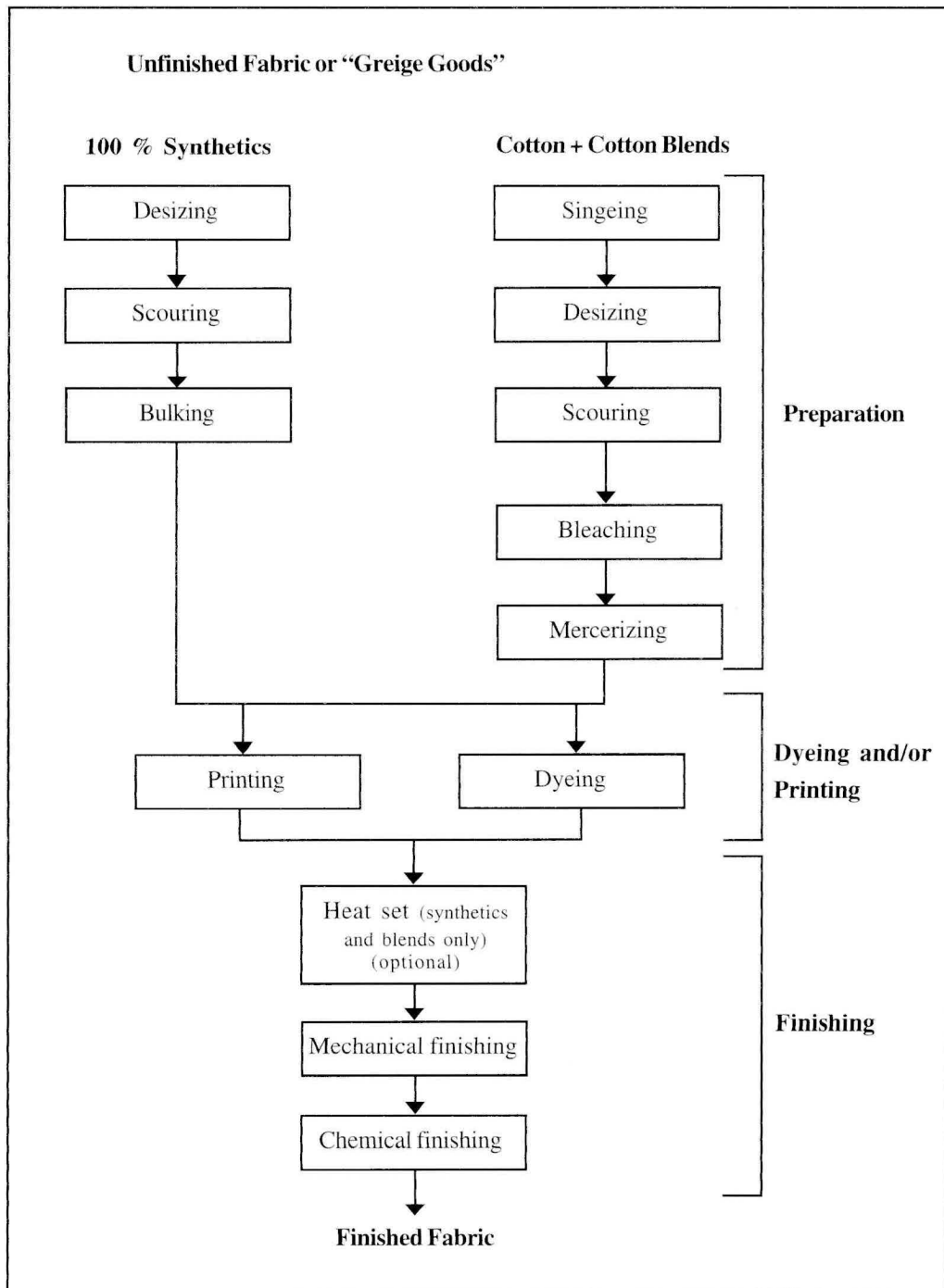
Woven and knit fabrics cannot be processed into apparel and other finished goods until the fabrics have passed through several water-intensive wet-processing stages. Wet processing enhances the appearance, durability, and serviceability of fabrics by converting undyed and unfinished goods, known as gray or greige goods, into finished consumers' goods. Also, collectively known as finishing, wet processing has been broken down into four stages in this section for simplification: fabric preparation, dyeing, printing, and finishing. These stages, shown in **Figure 8**, involve treating gray goods with chemical baths and often require additional washing, rinsing, and drying steps. It should be noted that some of these steps may be optional depending on the style of fabric being manufactured.

In terms of waste generation and environmental impacts, wet processing is the most significant textile operation. Methods used vary greatly depending on end products and applications, site-specific manufacturing practices, and fiber type. Natural fibers typically require more processing steps than manmade fibers. For most wool products and some manmade and cotton products, the yarn is dyed before weaving; thus, the pattern is woven into the fabric. Processing methods may also differ based on the final properties desired, such as tensile strength, flexibility, uniformity, and luster.

Most manufactured textiles are shipped from textile mills to commission dyeing and finishing shops for wet processing, although some firms have integrated wet processing into their operations. A wide range of equipment is used for textile dyeing and finishing. Much of the waste generated from the industry is produced during the wet processing stages. Relatively large volumes of wastewater are generated, containing a wide range of contaminants that must be treated prior to disposal. Significant quantities of energy are spent heating and cooling chemical baths and drying fabrics and yarns.

#### 3.2.3.1 Fabric Preparation

Most fabrics, with the exception of denim and certain knit styles, that are dyed, printed, or finished must first be prepared. Preparation or pretreatment, consists of a series of treatment and rinsing steps that are critical for good results in subsequent textile finishing processes. In preparation, the mill removes natural impurities or processing chemicals that interfere with dyeing, printing, and finishing. Typical preparation treatments include desizing, scouring, and bleaching. Preparation steps can also include processes, such as singeing and mercerizing, designed to chemically or physically alter the fabric. For instance, the mercerizing stage chemically treats the fabric to increase fiber strength and dye affinity, or ability to pick up dyes. This, in turn, increases the longevity of fabric finishes applied during finishing. Many of the pollutants from preparation result from the removal of previously applied processing chemicals and agricultural residues. These chemical residues can be passed on to subsequent stages with improper preparation.



Source: ATMI, 1997

Figure 8: Typical Wet Processing Steps for Fabrics

Most mills can use the same preparation equipment for the entire range of products they produce. In most cases, facilities favor continuous rather than batch preparation processes for economic and pollution control reasons. A number of mills, however, prepare goods, particularly knits, batchwise on dyeing machines to simplify scheduling and handling. Sometimes, facilities operate batchwise to reduce high capital costs required for high productivity and the complexity of storing and tracking goods through continuous wet processing operations.

Because preparation is relatively uniform across most of a mill's production, preparation is usually the highest-volume process in a mill and hence an important area for pollution prevention. If fabrics contained no contamination upon arrival for wet processing, preparation processes would be unnecessary, eliminating about half the pollution outputs from wet processing and a significant amount of wastewater. The primary pollutants from preparation are wastewater containing alkalinity, BOD, COD, and relatively small amounts of other contaminants such as metals and surfactants. There are many preparation techniques, some of which are described below.

- *Singeing:*

Singeing is essential for providing the fabric with a smooth finish. Singeing is a dry process used on woven goods that removes fibers protruding from yarns or fabrics. These are burned-off by passing the fibers over a flame or heated copper plates. Singeing improves the surface appearance of woven goods and reduces pilling. It is especially useful for fabrics that are to be printed or where a smooth finish is desired. Pollutant outputs associated with singeing include relatively small amounts of exhaust gases from the burners.

- *Desizing:*

Desizing is an important preparation step used to remove size materials applied prior to weaving. Manmade fibers are generally sized with water-soluble sizes that are easily removed by a hot-water wash or in the scouring process. Natural fibers such as cotton are most often sized with water-insoluble starches or mixtures of starch and other materials. Enzymes are used to break these starches into water-soluble sugars, which are then removed by washing before the cloth is scoured. Removing starches before scouring is necessary because they can react and cause color changes when exposed to sodium hydroxide in scouring.

- *Scouring:*

Scouring is a cleaning process that removes impurities from fibers, yarns, or cloth through washing. Alkaline solutions are typically used for scouring; however, in some cases solvent solutions may also be used. Scouring uses alkali, typically sodium

hydroxide, to break down natural oils and surfactants and to emulsify and suspend remaining impurities in the scouring bath. In specific scouring procedures, chemicals, temperature, and time vary with the type of fiber, yarn, and cloth construction. Impurities may include lubricants, dirt and other natural materials, water-soluble sizes, antistatic agents, and residual tints used for yarn identification. Desizing and scouring operations are often combined.

- *Bleaching:*

Bleaching is a chemical process that eliminates unwanted colored matter from fibres, yarns, or cloth. Bleaching decolorizes colored impurities that are not removed by scouring and prepares the cloth for further finishing processes such as dyeing or printing. Several different types of chemicals are used as bleaching agents, and selection depends on the type of fiber present in the yarn, cloth, or finished product and the subsequent finishing that the product will receive. The most common bleaching agents include hydrogen peroxide, sodium hypochlorite, sodium chlorite, and sulfur dioxide gas. Hydrogen peroxide is by far the most commonly used bleaching agent for cotton and cotton blends, accounting for over 90 percent of the bleach used in textile operations, and is typically used with caustic solutions. Bleaching contributes less than 5 percent of the total textile mill BOD load.

The bleaching process involves several steps: 1) the cloth is saturated with the bleaching agent, activator, stabilizer, and other necessary chemicals; 2) the temperature is raised to the recommended level for that particular fibre or blend and held for the amount of time needed to complete the bleaching action; and 3) the cloth is thoroughly washed and dried. Peroxide bleaching can be responsible for wastewater with high pH levels. Because peroxide bleaching typically produces wastewater with few contaminants, water conservation and chemical handling issues are the primary pollution concerns.

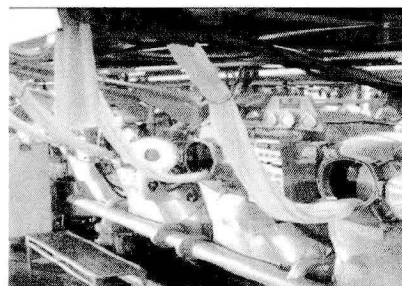
- *Mercerizing:*

Mercerization is a continuous chemical process used for cotton and cotton/polyester goods to increase dye ability, luster, and appearance. This process, which is carried out at room temperature, causes the flat, twisted ribbon-like cotton fibre to swell into a round shape and to contract in length. This causes the fiber to become more lustrous than the original fiber, increase in strength by as much as 20%, and increase its affinity for dyes. Mercerizing typically follows singeing and may either precede or follow bleaching.

During mercerizing, the fabric is passed through a cold 15-20% solution of caustic soda and then stretched-out on a tenter frame where hot-water sprays remove most of the caustic solution. After treatment, the caustic is removed by several washes under tension. Remaining caustic may be neutralized with a cold acid treatment followed by several more rinses to remove the acid.

### 3.2.3.2 Dyeing

Dyeing operations are used at various stages of production to add color and intricacy to textiles and increase product value. Most dyeing are performed either by the finishing division of vertically integrated textile companies, or by specialty dyehouses. Specialty dyehouses operate either on a commission basis, or purchase greige goods and finish them before selling them to apparel and other product manufacturers.



Dyeing & finishing plant

Textiles are dyed using a wide range of dyestuffs, techniques, and equipment. Dyeing can be performed using continuous or batch processes. Dyes used by the textile industry are largely synthetic, typically derived from coal tar and petroleum-based intermediates. Dyes are sold as powders, granules, pastes, and liquid dispersions, with concentrations of active ingredients ranging typically from about 20-80%.

In batch dyeing, a certain amount of textile substrate, usually 100 to 1,000 kilograms, is loaded into a dyeing machine and brought to equilibrium, or near equilibrium, with a solution containing the dye. Because the dyes have an affinity for the fibres, the dye molecules leave the dye solution and enter the fiber over a period of minutes to hours, depending on the type of dye and fabric used. Auxiliary chemicals and controlled dye-bath conditions (mainly temperature) accelerate and optimize the action. The dye is fixed in the fiber using heat and/or chemicals, and the tinted textile substrate is washed to remove unfixed dyes and chemicals. Common methods of batch, or exhaust dyeing include beam, beck, jet, and jig processing. Pad-dyeing can be performed by batch or continuous processes.

In continuous dyeing processes, textiles are fed continuously into a dye range at speeds usually between 50 and 250 meters per minute. Continuous dyeing accounts for about 60% of total yardage of product dyed in the industry. To be economical, this may require the dyer to process 10,000 meters of textiles or more per color, although specialty ranges are now being designed to run as little as 2,000 meters economically. Continuous dyeing processes typically consist of dye application, dye fixation with chemicals or heat, and washing. Dye fixation is a measure of the amount of the percentage of dye in a bath that will fix to the fibers of the textile material. Dye fixation on the fiber occurs much more rapidly in continuous dyeing than in batch dyeing.

Each dyeing process requires different amounts of dye per unit of fabric to be dyed. This is significant since color and salts in wastewater from spent dyes are often a pollution concern for textile facilities. In addition, less dye usage results in energy conservation and chemical savings. The amounts of dye used depend on the dye exhausted from the dye-baths which determines the required dye-bath ratio. The dye-bath ratio is the ratio of the units of dye required per unit of

fabric and typically ranges from 5 to 50 depending on the type of dye, dyeing system, and affinity of the dyes for the fibers.

Dyeing processes may take place at any of several stages of the manufacturing process (fibers, yarn, and piece dyeing). Stock dyeing is used to dye fibers. Top dyeing is used to dye combed wool sliver. Yarn dyeing and piece dyeing, done after the yarn has been constructed into fabric, are discussed in more detail below.

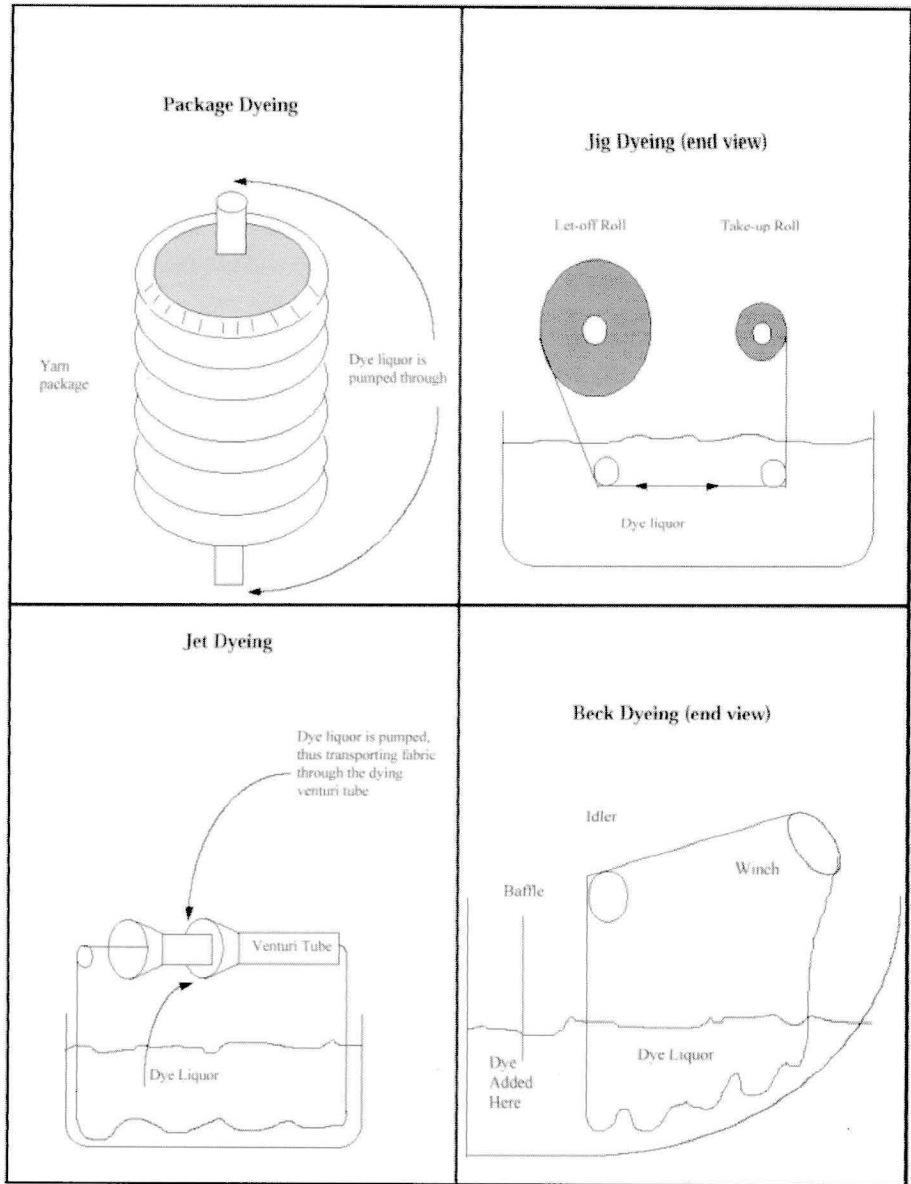
- *Yarn Dyeing:*

Yarn dyeing is used to create interesting checks, stripes, and plaids with different colored yarns in the weaving process. In yarn dyeing, dyestuff penetrates the fibers in the core of the yarn. Some methods of yarn dyeing are stock, package, and skein dyeing. Stock dyeing dyes fiber using perforated tubes. In package dyeing (refer **Figure 9**), spools of yarn are stacked on perforated rods in a rack and immersed in a tank where dye is then forced outward from the rods under pressure. The dye is then pressured back through the packages toward the center to fully penetrate the entire yarn. Most carded and combed cotton used for knitted outerwear is package-dyed. In skein-dyeing, yarn is loosely coiled on a reel and then dyed. The coils, or skeins, are hung over a rung and immersed in a dyebath. Skein-dyed yarn is used for bulky acrylic and wool yarns. Typical capacity for package dyeing equipment is 550 kg and for skein dyeing equipment is 100 kg.

- *Piece Dyeing:*

Most dyed fabric are piece-dyed as this method gives the manufacturer maximum inventory flexibility to meet color demands as fashion changes. In terms of overall volume, the largest amount of dyeing is performed using beck (winch) and jig equipment (refer **Figure 9**). Beck (winch) dyeing is a versatile, continuous process used to dye long yards of fabric. About 900 kg of fabric can be dyed on beck equipment at a time. The fabric is passed in rope form through the dyebath. The rope moves over a rail onto a reel, which immerses it into the dye and then draws the fabric up and forward to the front of the machine. This process is repeated as long as necessary to dye the material uniformly to the desired color intensity. Jig dyeing uses the same procedure of beck dyeing, however, the fabric is held on rollers at full width rather than in rope form as it is passed through the dyebath. This reduces fabric tendency to crack or crease. Jig dyeing equipment can handle 250 kg of fabric.

Other piece dyeing methods include jet (rapid) dyeing and pad dyeing. Fabric can be jet-dyed at up to 500 kg by placing it in a heated tube or column where jets of dye



Source: *Best Management Practices for Pollution Prevention in the Textile Industry*, EPA, Office of Research and Development, 1995

**Figure 9: Common Dyeing Methods**

solution are forced through it at high pressures. The dye is continually recirculated as the fabric is moved along the tube. Pad-dyeing, like jig-dyeing, dyes the fabric at full width. The fabric is passed through a trough containing dye and then between two heavy rollers which force the dye into the cloth and squeeze out the excess. **Figure 9** illustrates the beck, jig, and jet methods for dyeing.

- Types of Dyes:

Dyes may be classified in several ways, according to chemical constitution, application class, end-use. The primary classification of dyes is based on the fibers to which they can be applied and the chemical nature of each dye. **Table 3** lists the major dye classes, fixation rates, and the types of fibers for which they have an affinity. Factors that are considered in selecting a dye include the type of fibers being dyed, desired shade, dyeing uniformity, and fastness.

Most commonly used dyes today are the reactive and direct types for cotton dyeing, and disperse types for polyester dyeing.

Dyes have the following properties:

- Reactive dyes react with fiber molecules to form chemical bonds.
- Direct dyes can color fabric directly in one operation and without the aid of an affixing agent.
- Direct dyes are the simplest to apply and cheapest in their initial and application costs, although there are trade-offs in the dyes' shade range and wet-fastness.
- Direct and reactive dyes have a fixation rate of 90-95% and 60-90%, respectively.
- A variety of auxiliary chemicals may be used during dyeing to assist in dye absorption and fixation into the fibers.
- Disperse dyes, with fixation rates of 80-90%, require additional factors, such as dye carriers, pressure, and heat, to penetrate synthetic fibers.
- Disperse dyes are dispersed in water where the dyes are dissolved into fibers.
- Vat dyes, such as indigo, are also commonly used for cotton and other cellulosic fibers.

Table 3: Typical Characteristics of Dyes Used in Textile Dyeing Operations

Dye Class	Description	Method	Fibres Typically Applied to	Typical Fixation (%)	Typical Pollutants Associated with Various Dyes
Acid	Water-soluble anionic compounds	Exhaust/Beck/ Continuous (carpet)	Wool, Nylon	80-93	Color; organic acids; unfixed dyes
Basic	Water-soluble, applied in weakly acidic dyebaths; very bright dyes	Exhaust/Beck	Acrylic, some polyesters	97-98	N/A
Direct	Water-soluble, anionic compounds; can be applied directly to celluloses without mordants (or metals like chromium and copper)	Exhaust/ Beck/ Continuous	Cotton, Rayon, Other celluloses	70-95	Color; salt; unfixed dye; cationic fising agents; surfactant; defoamer; leveling and retarding agents; finish; diluents
Disperse	Not water-soluble	High temperature exhaust/ Continuous	Polyester Acetate, other synthetics	80-92	Color; organic acids; carriers; leveling agents; phosphates; defoamers; lubricants; dispersants; delustrants; diluents
Reactive	Water-soluble, anionic compounds; largest dye class	Exhaust/Beck Cold Pad Batch/ Continuous	Cotton, other celluloses, wool	60-90	Color; salt; alkali; unfixed dye; surfactants; defoamer; diluents; finish
Sulfur	Organic compounds containing sulfur or sodium sulfide	Continuous	Cotton, other celluloses	60-70	Color; alkali; oxidizing agents; reducing agent; unfixed dye
Vat	Oldest dyes; more chemically complex; water-insoluble	Exhaust/ Package/ Continuous	Cotton, other celluloses	80-95	Color; alkali; oxidizing agent; reducing agents

### 3.2.3.3 Printing

Fabrics are printed with color and patterns using a variety of techniques and machine types. The most common printing technique is rotary screen, while other printing methods are also used commercially as described below.

Pigments used for about 75-85% of all printing operations do not require washing steps, and generate little wastewater. Compared to dyes, pigments are typically insoluble and have no affinity for the fibers. Resin binders are typically used to attach pigments to substrates. Solvents are used as vehicles for transporting the pigment and resin mixture to the substrate. The solvents then evaporate leaving a hard opaque coating.

The major types of printing techniques are described in **Annex A**.

### 3.2.3.4 Finishing

Finishing encompasses chemical or mechanical treatments performed on fiber, yarn, or fabric to improve appearance, texture, or performance. Mechanical finishes can involve brushing, ironing or other physical treatments used to increase the luster and feel of textiles. Application of chemical finishes to textiles can impart a variety of properties ranging from decreasing static cling to increasing flame resistance. The most common chemical finishes are those that ease fabric care, such as the permanent-press, soil-release, and stain-resistant finishes. Chemical finishes are usually followed by drying, curing, and cooling steps. Application of chemical finishes are often done in conjunction with mechanical finishing steps.

The selected mechanical and chemical finishing techniques are described in **Annex B**.

## 3.2.4 Fabrication

Finished cloth is fabricated into a variety of apparel and household and industrial products. The simpler of these products, such as bags, sheets, towels, blankets, and draperies, often are produced by the textile mills themselves. Apparel and more complex housewares are usually fabricated by the cutting trades. Before cutting, fabrics must be carefully laid out. Accuracy in cutting the lay fabric is important since any defects created at this point may be carried through other operations and end up in the final product. For simple household and industrial products, sewing is relatively straightforward. The product may then be pressed to flatten the fabric and create crisp edges.



Cutting fabric

### 3.2.5 Carpet Manufacture

Carpet mills form a distinct part of the textile industry. Carpet mills use mostly synthetic fibres (nylon, acrylics and polyesters), but some wool and cotton are processed. The carpet mill category is characterised by any or all of the following operations:

- Bleaching
- Scouring
- Carbonizing (a phenomenon where a carbonaceous material is decomposed leaving a residue of essentially black carbon)
- Dyeing
- Printing
- Resin treatment
- Water proofing
- Flame proofing
- Soil repellency
- Backing with foamed and unfoamed latex and jute

Although some carpets are backed with latex in a separate plant, most 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 propylene and 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. Printing involves a semi-continuous screen printing operation followed by a wash-and-rinse step in the same machine. In dyeing, the most common method is beck (winch) dyeing.

## 3.3 SOURCES OF WASTE GENERATION

### 3.3.1 General Categorisation of Textile Mills

Textile processing generates many waste streams, including wastewater, air emissions, solid wastes and hazardous wastes. The nature of the waste generated depends on the type of textile manufacturing facility, the processes and technologies being operated and the types of fibres

and chemicals used. In Malaysia, the textile manufacturing facilities carrying-out the various processes may be conveniently categorised as follows:

- Natural Fibre Spinning and Weaving Mills:
  - Yarn formation processes
  - General fabric formation processes used for producing flat fabrics.
  
- Dyeing, Bleaching, Printing and Finishing of Yarn and Fabric Mills:
  - These operations incorporate the typical wet processing for fabrics.
  
- Synthetic Textile Mills:
  - Production of synthetic fibres
  - Yarn formation processes using manmade filament and staple fibres
  - General fabric formation processes used for producing flat fabrics
  - Typical wet processing for fabrics
  
- Knitting Mills:
  - General fabric formation processes used for producing flat fabrics
  - Typical wet processing for producing fabrics from knit “greige goods”
  
- Carpet Mills
  - Use mostly synthetic fibres such as nylon, acrylics and polyesters
  - Some wool and cotton are also processed
  - Carpets are backed with latex in a separate plant or in the same plant with the finishing
  - Printing involves a semi-continuous screen printing operation and a wash-and-rinse step in the same machine
  - The most common dyeing method used is beck (winch) dyeing.

### 3.3.2 Potential Sources of Waste Generation

The potential sources of waste generation and pollution associated with the various textile manufacturing processes are summarised in **Table 4**. Details regarding the individual waste streams and their typical characteristics are deferred for presentation in Chapter 4, which deals with the environmental issues of the textile industry.

### 3.3.3 Other Sources of Waste Materials

Primary residual wastes are also generated by the textile industry which are generally non-hazardous. These include fabric and yarn scrap, off-specification yarn, and fabric and packaging waste. Cutting room waste is kept to a minimum by increasing fabric utilisation efficiency in cutting and sewing. Cotton trash leaves and stems collected during yarn formation are sometimes sold to livestock farmers as animal feed.

**Table 4: Potential Sources of Waste Generation in Textile Manufacturing**

Process	Air Emissions	Wastewater	Residual Wastes
Fibre preparation	Little or no air emissions generated	Little or no wastewater generated	Fibre waste; packaging waste and hard waste
Yarn spinning	Little or no air emissions generated	Little or no wastewater generated	Packaging wastes; sized yarn; fibre waste; cleaning and processing waste
Slashing/sizing	VOCs	BOD; COD; metals; cleaning waste, size	Fibre lint; yarn waste; packaging waste; unused starch-based sizes;
Weaving	Little or no air emissions generated	Little or no wastewater generated	Packaging waste; yarn and fabric scraps; off-spec fabric; used oil
Knitting	Little or no air emissions generated	Little or no wastewater generated	Packaging waste; yarn and fabric scraps; off-spec fabric
Tufting	Little or no air emissions generated	Little or no wastewater generated	Packaging waste; yarn and fabric scraps; off-spec fabric
Desizing	VOCs from glycol ethers	BOD from water-soluble sizes; synthetic size; lubricants; biocides; anti-static compounds	Packaging waste; fibre lint; yarn waste; cleaning materials, such as wipes, rags, and filters; cleaning and maintenance wastes containing solvents.
Scouring	VOCs from glycol ethers and scouring solvents	Disinfectants and insecticide residues; NaOH; detergents, fats; oils; pectin; wax; knitting lubricants; spin finishes; spent solvents.	Little or no residual waste generated
Bleaching	Little or no air emission generated	Hydrogen peroxide, sodium silicate or organic stabilizer; high pH	Little or no residual waste generated

**Table 4: Potential Sources of Waste Generation in Textile Manufacturing (cont.)**

<b>Process</b>	<b>Air Emissions</b>	<b>Wastewater</b>	<b>Residual Wastes</b>
Singeing	Small amounts of exhaust gases from the burners	Little or no wastewater generated	Little or no residual waste generated
Mercerizing	Little or no air emission generated	High pH; NaOH	Little or no residual waste generated
Heatsetting	Volatilization of spin finish agents applied during synthetic fibre manufacture	Little or no wastewater generated	Little or no residual waste generated
Dyeing	VOCs	Metals; salts; surfactants; toxins; organic processing assistants; cationic materials; color; BOD; COD; sulfide; acidity/alkalinity; spent solvents	Little or no residual waste generated
Printing	Solvents, acetic acid from drying and curing oven emissions; combustion gases; particulate matter	Suspended solids; urea; solvents; color; metals; heat; BOD; foam	Little or no residual waste generated
Finishing	VOCs; contaminants in chemicals; formaldehyde vapors; combustion gasses; particulate matter	BOD; COD; suspended solids; toxins; spent solvents	Fabric scraps and trimmings; packaging waste
Product fabrication	Little or no air emissions generated	Little or no wastewater generated	Fabric scraps

*Source: Best Management Practices for Pollution Prevention in the Textile Industry, EPA, Office of Research and Development, 1995*

## **4.0 ENVIRONMENTAL ISSUES**

### **4.1 INTRODUCTION**

Textile mills may typically generate:

- Large quantities of wastewater with high organic content and typically coloured, if untreated;
- Hazardous chemical wastes and residues;
- Non-hazardous solid waste materials; and
- Noise

The environmental issues of the textile industry are primarily related to:

- Water pollution due to indiscriminate discharge of untreated or partially treated effluents into public watercourses;
- Improper interim storage of chemicals and solid waste materials;
- Localised and minor air pollution due to boilers, ovens and solvent-based cleaning activities;
- Noise;
- Odour in some processing areas; and
- Occupational exposure to solvents and certain hazardous chemicals

### **4.2 TEXTILE MILL EFFLUENTS**

#### **4.2.1 Effluent Quantities and Characteristics**

The combined factory effluent constitutes the largest waste stream of the textile industry. The principal sources of wastewater include cleaning water, process water, non-contact cooling water and stormwater. The amount of water used varies widely in the industry, depending on the specific processes operated at the mill, the equipment used, and the prevailing management philosophy regarding water use. On average, approximately 165 liters of water are required to process 1 kilogram of textile.

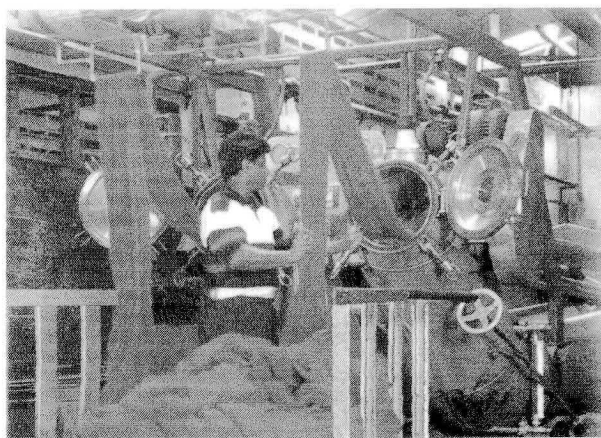
The significant sources of effluent include wastewater from preparation and continuous dyeing, alkaline wastewater from preparation, and batch discharges of dye waste containing large amounts of salt, acid or alkali. The wet processing operations which include preparation, dyeing and finishing generate the major portion of textile wastewater. Because of the wide variety of process steps, textile wastewater typically contains a complex mixture of chemicals.

Desizing, the process of removing size chemicals from textiles, is one of the industry's largest sources of water pollution. In this process, large quantities of size used in weaving processes are typically discarded. Starch, the most common primary size component, is used on natural fibres and in a blend with synthetic sizes for coating natural and synthetic yarns. Polyvinyl alcohol (PVA), the leading synthetic size, accounts for much of the remaining size consumed. PVA is increasing in use since it can be recycled, unlike starch. PVA is used with polyester/cotton yarns and pure cotton yarns either in pure form or in blends with natural and other synthetic sizes. Other synthetic sizes contain acrylic and acrylic copolymer components. Semi-synthetic sizes such as carboxymethyl cellulose (CMC) and modified starches are also used.

Oils, waxes, and other additives are often used in conjunction with sizing agents to increase the softness and pliability of the yarns. About 10-15% of the weight of goods is added as size to cotton warp yarns, compared to about 3-5% for filament synthetics.

In the scouring and cleaning processes, the impurities that are removed from fibers, yarns, or cloth through washing may include lubricants, dirt and other natural materials, water-soluble sizes, antistatic agents, and residual tints used for yarn identification. Typically, scouring wastes contribute a large portion of biological oxygen demand (BOD) loads from preparation processes. Desizing and scouring operations are often combined.

Primary sources of biological oxygen demand (BOD) include waste chemicals or batch dumps, starch-based sizing agents, knitting oils and degradable surfactants. Desizing and scouring processes often contribute up to 50% of the BOD load in wastewater from wet processing. **Table 5** shows typical BOD loads from the preparation processes.



**Dyeing and finishing processes generate a substantial amount of effluent**

Table 5: Typical BOD Loads from Preparation Processes

Process Operation	Kilograms of BOD per 1,000 Kilograms of Production
Singeing	0
Desizing	
- Starch	67
- Starch, mixed size	20
- PVA or CMC	0
Scouring	40-50
Bleaching	
- Peroxide	3-4
- Hypochlorite	8
Mercerizing	15
Heat-setting	0
PVA = polyvinyl alcohol; CMC = carboxymethyl cellulose	

*Source: Best Management Practices for Pollution Prevention in the Textile Industry, EPA Office of Research and Development, 1995*

Mercerization is a continuous chemical process used for cotton and cotton/polyester goods to increase dye ability, luster, and appearance. During mercerizing, the fabric is passed through a cold 15-20% solution of caustic soda and then stretched-out on a tenter frame where hot-water sprays remove most of the caustic solution. After treatment, the caustic is removed by several washes under tension. Remaining caustic may be neutralized with a cold acid treatment followed by several more rinses to remove the acid. Wastewater from mercerizing can contain substantial amounts of high pH alkali, accounting for about 20% of the weight of goods.

Dyeing operations generate a large portion of the industry's total wastewater. The primary source of wastewater in dyeing operations is spent dye-bath and wash waters. Such wash waters typically contain by-products, residual dye and auxiliary chemicals. Additional pollutants originate from the cleaning processes for disperse dyeing which generate about 100 to 140 liters of wastewater per kilogram of product. Similar processes for reactive and direct dyeing generate about 125-165 liters of wastewater per kilogram of product.

Finishing processes typically generate wastewater containing natural and synthetic polymers and a range of other potentially toxic substances. Pollution from peroxide bleaching normally is not a major concern. In most cases, scouring has removed impurities in the goods, so the only by-product of the peroxide reaction is water. The high volume of effluent in the bleaching process are chemical handling, water conservation and high pH.

Hazardous waste generated by textile manufacturers results primarily from the use of solvents in cleaning knit goods. Solvents may be used in some scouring or equipment cleaning operations, however, more often scouring processes are aqueous-based and cleaning materials involve mineral spirits or other chemicals. Spent solvents may include tetrachloroethylene and trichloroethylene.

Other water pollutants are essentially colour and salts. Their sources are as follows:

#### Colour:

Dyes and pigments from printing and dyeing operations are the principal sources of colour in textile effluent. Dyes and pigments are highly coloured materials used in relatively small quantities (a few percent or less of the weight of the substrate) to impart colour to textile materials for aesthetic or functional purposes. In typical dyeing and printing processes 50 to 100 % of the colour is fixed on the fibre. The remainder is discarded in the form of spent dye-baths or in wastewater from subsequent textile-washing operation.

#### Salt:

Salts in textile-dyeing wastewater have been identified as potential problem area. Many types of salt are either used as raw materials or produced as by-products of neutralisation or other reactions in textile wet processes. Salt is used mostly to assist the exhaustion of ionic dyes, particularly anionic dyes, such as direct and fibre reactive dyes on cotton. Typical cotton batch dyeing operations use quantities of salt that range from 20-80% of the weight of goods dyed and usual salt concentration in such wastewater is 2,000-3,000 mg/L. Common salt (sodium chloride) and Glaubers salt (sodium sulfate) constitute the majority of total salt use. Other salts used as raw materials or formed in textile processes include Epsom salt (magnesium chloride), potassium chloride and others in low concentrations.

#### Metals:

Many textile mills have few or no metals in their effluent, but whenever metals are present they may include copper, cadmium, chromium, nickel and zinc. Sources of metals found in textile mill effluents may include fiber, incoming water, dyes, plumbing and chemical impurities. Dyes may contain metals such as zinc, nickel, chromium and cobalt. In some dyes these metals are functional

(i.e. they form an integral part of the dye molecule); however, in most dyes, metals are generally impurities generated during dye manufacture. For example, mercury or other metals may be used as catalysts in the manufacture of certain dyes and may be present as by-products.

#### *Aquatic Toxicity:*

The aquatic toxicity of textile industry wastewater varies considerably among production facilities.

Data are available that show that the wastewater of some facilities has fairly high aquatic toxicity, while others show little or no toxicity. The sources of aquatic toxicity can include:

- Salt
- Surfactants
- Ionic metals and their complexed forms
- Toxic organic chemicals
- Biocides
- Toxic anions

Most textile dyes have low aquatic toxicity. On the other hand, surfactants and related compounds, such as detergents, emulsifiers, dispersants, are used in almost every textile process and can be an important contributor to effluent aquatic toxicity, BOD and foaming.

### **4.2.2 Typical Effluent Quality Characteristics of Textile Mills**

The typical effluent quality characteristics of textile mills in Malaysia based on the various textile manufacturing process operations encountered are presented in **Table 6**.

### **4.3 Air Emissions**

Although the textile industry is a relatively minor source of air pollutants compared with many other industries, a wide variety of air pollutants are emitted by the textile industry. Operations that represent the greatest concern are coating, finishing and dyeing operations. Textile mills usually generate nitrogen and sulfur oxides from boilers.

Other significant sources of air emissions in textile operations include resin finishing and drying operations, printing, dyeing, fabric preparation and wastewater treatment plant operations.

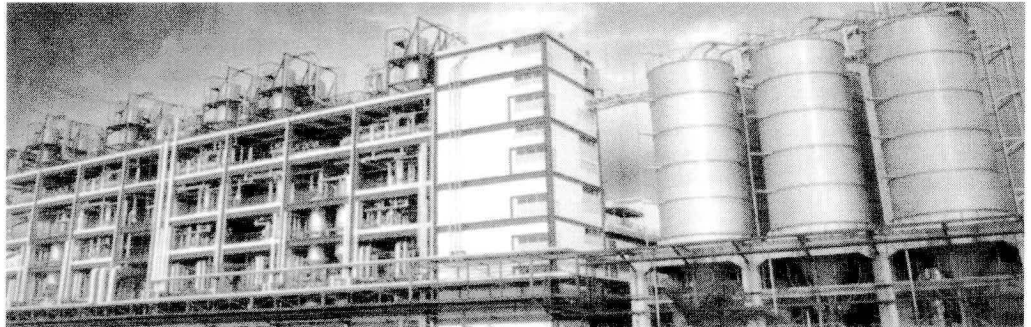
**Table 6: Typical Textile Mill Effluent Characteristics Based on Type of Manufacturing Operations**

TYPE OF TEXTILE MILL/ TEXTILE MANUFACTURING OPERATIONS	WASTEWATER CHARACTERISTICS							
	pH	BOD, mg/L (5-day; 20oC)	COD, mg/L	TSS, mg/L	Oil & Grease, mg/L	Metals, mg/L	Other, mg/L	Wastewater Volume, Liter/Kilogram Textile
1. Natural Fiber Spinning and Weaving Mills	1.0	350	1,000	200	-	-	-	1.5
2. Dyeing, Bleaching, Printing and Finishing of Yarn and Fabric	1.0	650	1,200	300	14	T o t a l Chromium: 0.04	Phenol: 0.04 Sulphide: 3.0	13.5
3. Knitting Mills	8.0	350	1,000	300	53	T o t a l Chromium: 0.05	Phenol: 0.24 Sulphide: 0.20	18
4. Synthetic Mills	4-5	900	1,800	-	-	-	-	-

Hydrocarbons from mineral oil from high temperature (200°C) drying and curing. These processes can emit formaldehyde, acids, softeners, and other volatile compounds. Residues from fibre preparation sometimes emit pollutants during heat-setting processes.

Carriers and solvents may be emitted during dyeing operations depending on the types of dyeing processes used, and from wastewater treatment plant operations. Carriers used in batch dyeing of disperse dyes may lead to volatilisation of aqueous chemical emulsions during heat setting, drying or curing stages. Acetic acid and formaldehyde are two major emissions of concern in textiles.

Other potential pollutants can include solvent vapours containing toxic compounds such as acetaldehyde, chlorofluorocarbons, p-dichlorobenzene, ethyl acetate and others. Some process chemicals, such as methyl naphthalene or chlorotoluene, may exhaust into the fibers and later emitted from dryers as VOCs. Formaldehyde might be emitted from bulk resin storage tanks, finished fabric warehouses, dryers, and curing ovens located at facilities that apply formaldehyde-containing resins to cotton and polyester/cotton blends. Textile manufacturing can produce oil and acid fumes, plasticizers and other volatile chemicals. Acetic acid emissions may arise from storage tanks, especially from vents during filling.



**Polyester Staple Fibre Plant uses volatile chemicals**

## **5.0 REGULATORY FRAMEWORK**

### **5.1 INTRODUCTION**

The Environmental Quality Act 1974 (EQA), together with its amendments (Act A636, A953 and A 1030), is the most comprehensive legislation in operation for the prevention, abatement, control of pollution and enhancement of the environment. The EQA is a Federal legislation and therefore enforced by a Federal agency, the Department of Environment (DOE), under the administration of the Director General of Environmental Quality.

Under the Environmental Quality Act 1974, environmental control of the textile industry is exercised through a non-industry-specific approach involving the application of the following enabling provisions and powers of the Act:

- **Section 21:** Powers to prohibit, restrict, or specify acceptable conditions of the emission, discharge or deposit of wastes or the emission of noise into any area, segment or element of the environment; and
- **Section 51:** Powers to exercise control or regulate through the formulation of regulations.

The textile industry is subject to environmental control under the following specific regulations:

- Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979 - for control of effluent discharge;
- Environmental Quality (Clean Air) Regulations, 1978 - for control of air emissions; and
- Environmental Quality (Scheduled Wastes) Regulations, 1989 - for control of the ultimate disposal of toxic and hazardous wastes.

There also exist other pieces of legislation administered by Federal, State and Local Government authorities which have certain provisions for environmental control that can be generally applied to textile mills. The exercise of environmental control (if any) under such legislation is usually *ad-hoc* and also non-industry-specific, and these are therefore not discussed in this Handbook.

## 5.2 ENVIRONMENTAL QUALITY ACT, 1974 & AMENDMENTS

In brief, the Environmental Quality Act 1974:

- Came into force on April 15, 1975;
- Has since been amended 3 times: in 1985, 1996 and 1998, respectively,

to increase its effectiveness:

- Has 26 pieces of subsidiary legislation: 13 sets of regulations; 2 sets of rules and 11 sets of orders (as at 1st October 2000) for the exercise of control over pollution sources.

The 1996 amendment of the EQA was particularly significant in that, among others, it:

- Increased the penalties for offences from RM 10,000 to RM 100,000;
- Empowered the DOE to inspect an offending site without a warrant; and
- Authorised the DOE to request for an environmental audit, if deemed necessary;
- Provided for the application of market-based instruments (MBIs) and economic incentives such as deposit and rebate schemes.

The major changes in the recent 1998 amendment were:

- Prohibition on open-burning except the activities being prescribed by the Minister;
- Prosecution can be instituted with the consent of the Public Prosecutor; and
- Penalty for open-burning has been increased from RM 100,000 to RM 500,000.

## 5.3 REGULATORY CONTROL OF THE TEXTILE INDUSTRY

### 5.3.1 Control of Effluent Discharges

The Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979, promulgated under the enabling powers of Section 51 of the EQA, are the overall governing regulations that contain the effluent discharge standards and other regulatory requirements applicable to industry at large as well as textile factories.

The principal regulatory requirements and elements of regulatory control for industrial effluents are:

- Written permission shall be obtained from the Director-General of Environment for the establishment of a new textile mill, or for any material change in the quantity or quality of the discharge from an existing textile mill (Part II);
- All textile mills shall comply with the relevant effluent parameter limits of Standard A or Standard B in *Annex C* of this Handbook prior to discharge into inland waters. Standard A is applicable to discharge into inland waters within the water-supply catchment areas and Standard B for discharge into all other inland waters (Part III);
- Effluent or any other forms of waste shall not be discharged onto any soil or surface of land without the prior written permission of the Director-General of Environment (Part IV);
- Regulatory offences related to effluent discharge are liable to a fine of up to RM 100,000, or to imprisonment for up to 5 years, or to both, and to a further fine of up to RM 1,000 per day for a continuing offence (Section 25(3) of EQA);

Factories that are faced with genuine difficulty in complying with the effluent discharge standards can apply to the DOE for a temporary contravention licence for such specific period as approved by the Director-General; an effluent-related fee is charged for this license (Part V).

### 5.3.2 Control of Air Emissions

The textile industry is not a major source of air pollution, but emissions from boilers, ovens, solvent-based cleaning activities and other fugitive sources may arise.

The textile industry is directly subject to the requirements of the Environmental Quality (Clean Air) Regulations, 1978 with respect to air emissions.

The following provisions of the Clean Air Regulations are generally applicable to textile factories on the basis of their relevance:

- Written permission of the Director-General of Environment shall be obtained for the siting of new factories adjacent to residential areas (Part II);
- Burning of trade waste is permitted only in an incinerator approved by the Director-General (Part III);
- Control requirements for dark smoke emission (Part IV);
- Control requirements for emission of air impurities (Part V);
- Based on the relevance of specific parameters, the Air Emission Standard C for new facilities and Standard B for existing facilities in Part V of the Clean Air Regulations are generally to textile mills - refer *Annex D* of this Handbook ;
- Regulations 32 of the Clean Air Regulations requires the application of the best practicable means to control the emission of the noxious and offensive substances listed in the Third Schedule - refer *Annex D* of this Handbook.
- Regulation 36 of the Clean Air Regulations requires the prior written approval of the Director-General of Environment for the erection of any fuel-burning equipment;

Air emissions that do not comply with the Emission Standards given in *Annex D* constitute a major offence and shall be liable to a fine of up to RM 100,000, or to imprisonment for up to 5 years, or to both, and to a further fine of up to RM 1,000 per day for a continuing offence in accordance with Section 22(3) of the EQA. However a licence could be obtained from the Director-General to contravene the Standards for a specific period, in accordance with Regulation 49 of the Clean Air Regulations on grounds of genuine difficulty experienced in meeting the standards.

### 5.3.3 Control of Noise Emission

With the exception of regulations for the control of noise from motor vehicles, there are currently no regulations under the EQA for the control of noise from other sources such as industrial, construction, community noise, etc.

Regulations under the EQA for the control of noise from various sources and activities are still at the drafting stage. These regulations stipulate acceptable ambient noise levels at the receptor level for various situations to safeguard public health. The World Health Organisation (WHO) has also recommended various limits for noise levels for purposes of ear protection and human well-being.

However, noise is not a major issue in the textile industry. The DOE Guidelines on the Siting and Zoning of Industries, 1976 (revised 1994) specifies guideline noise emissions limits to be observed at the perimeter fence of factories - refer Annex F.

#### 5.3.4 Control of Toxic and Hazardous Waste (Scheduled Wastes) Disposal

The disposal of hazardous wastes, which are classified and regulated as scheduled wastes by DOE, are governed by the following subsidiary legislation of the EQA:

- The Environmental Quality (Scheduled Wastes) Regulations, 1989.

The principal regulatory provisions governing the generation and disposal of scheduled wastes as per The Scheduled Wastes Regulations are summarised in Annex E of this Handbook. In general, textile mills that generate scheduled wastes from within their production processes or as a result of waste treatment processes must comply with the following requirements

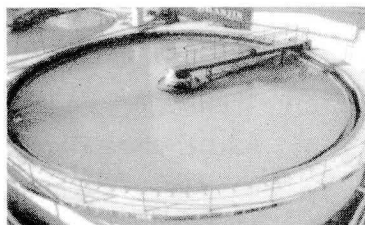
- The generator of any waste falling under the categories listed in the First Schedule of the Scheduled Wastes Regulations shall notify the Director-General of Environment within one month of its generation in the prescribed form (Regulations 2 and 3);
- Scheduled wastes shall be disposed of only at prescribed premises (Regulation 4);
- Treatment of scheduled wastes can be carried out only at prescribed premises or at on-site treatment facilities (Regulation 5);
- Every waste generator shall ensure that:
  - the best practicable means are used to minimise the waste generated to the extent practicable (Regulation 6);
  - scheduled wastes generated are properly stored as stipulated in Regulation 8, treated on-site or delivered to and received at prescribed premises for treatment or disposal (Regulation 7);
- Waste generators shall keep an up-to-date inventory of scheduled wastes generated, treated and disposed of (Regulation 9);
- Transportation of scheduled wastes from the place of generation to the disposal facilities shall conform to the consignment system as detailed in Regulation 10;
- The waste generator shall provide full information to the transport contractor on the nature of waste transported;

Illegal disposal of any scheduled wastes as provided for in Section 34B of the EQA is an offence and any person found guilty of this offence is liable to a fine of up to RM 500,000, or to imprisonment of up to 5 years, or both.

## **6.0 POLLUTION CONTROL PRACTICES**

### **6.1 INTRODUCTION**

Emission standards incorporated into the regulations are the main instruments of pollution control for the industrial sector. The factories are therefore required to install and operate appropriate wastewater treatment systems and pollution abatement and prevention equipment to enable compliance with the relevant emission standards stipulated in the various regulations.



This Chapter describes the state-of-the-art with respect to available technologies for the end-of-pipe treatment of wastes that have been adopted by the textile industry in relation to the different categories of textile mills in operation.

### **6.2 EFFLUENT TREATMENT TECHNOLOGIES FOR THE TEXTILE INDUSTRY**

#### **6.2.1 General**

The wastewater treatment technologies and systems employed by the textile industry are broadly similar for the following categories of textile mills:

- Natural fibre spinning and weaving mills
- Mills performing dyeing, bleaching, printing and finishing of yarn and fabric
- Knitting mills
- Synthetic textile mills

The textile industry generally employs wastewater treatment technologies and systems based on various combinations of physical unit operations and chemical/biological treatment unit processes, which include the followings:

- Screening
- Equalisation
- Chemical treatment/dissolved air floatation/ultrafiltration
- Primary clarification

- Biological treatment consisting of one of the following systems: Activated Sludge Process, Sequencing Batch Reactor (SBR), Oxidation Ditch System, Up-flow Anaerobic Sludge-Blanket (UASB) Reactor
- Secondary Clarification
- Sludge Treatment and Disposal

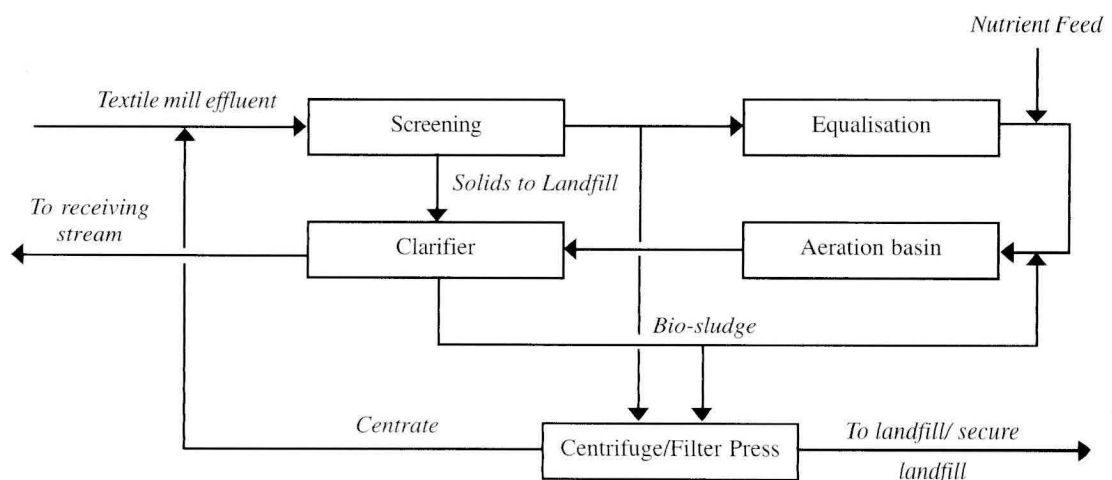
### 6.2.1.1 Natural Fibre Spinning and Weaving Mills

**Figure 10** is a process flow diagram representing a typical wastewater treatment technology for combined wastewater from natural fibre spinning and weaving processes to meet the effluent standards stipulated in the Sewage and Industrial Effluents Regulations. It incorporates the conventional activated sludge process for biological treatment of the biodegradable organic matter present.

The facility consists of the following treatment units:

- Screening
- Equalisation
- Conventional Activated Sludge System
- Centrifuge or Filter Press( for sludge treatment and disposal)

The conventional activated sludge process is used with addition of adequate nutrients to maintain the appropriate C:N ratio to facilitate biological oxidation.



**Figure 10 :** Typical Treatment Technology for Combined Wastewater from Natural Fibre Spinning and Weaving Processes

The resulting biological sludge of about 1.5 to 2.5% solids content can be dewatered using a horizontal solid bowl centrifuge or filter press. A cationic polymer is used as a conditioner to facilitate dewatering. The centrate/filtrate is returned to join the mill effluent stream entering the treatment facility. The sludge from the centrifuge/filter press may be sent to the sanitary landfill for disposal if it is ascertained to be non-toxic. Otherwise, it has to be sent to a secure landfill at an off-site scheduled waste treatment plant such as Kualiti Alam at Bukit Nenas, Negeri Sembilan.

### 6.2.1.2 Mills Performing Dyeing, Bleaching, Printing and Finishing

**Figure 11** is a process flow diagram representing a typical wastewater treatment technology for combined wastewater from textile mills performing the wet process operations of dyeing, bleaching, printing and finishing in order to meet the effluent standards stipulated in the Sewage and Industrial Effluents Regulations. It also incorporates the conventional activated sludge process for biological treatment of the biodegradable organic matter present.

However, due to the presence in the wastewater of fine colloidal suspended materials derived from the dyes and pigments used, which are not so readily biodegradable, such additional physico-chemical treatment process units as pH adjustment, coagulation and flocculation are necessary to remove these materials.

The treatment facility consists of the treatment process units described below.

- *Screening:*

Cotton impurities, fibre and other solids are removed by fine mesh screening. A screen with a mesh size of 80 has been effective for this application.

- *Biological Treatment:*

The activated sludge system is most effective for woven or knit fabric wastes when designed with extended aeration and a retention time of 3 to 5 days. Nitrogen deficiencies may be frequently found. Aqueous ammonia or anhydrous ammonia may be added to the raw wastewater prior to its entry to the aeration basin to overcome the nitrogen-deficiency. The phosphorus nutrient content is generally adequate for the activated sludge process.

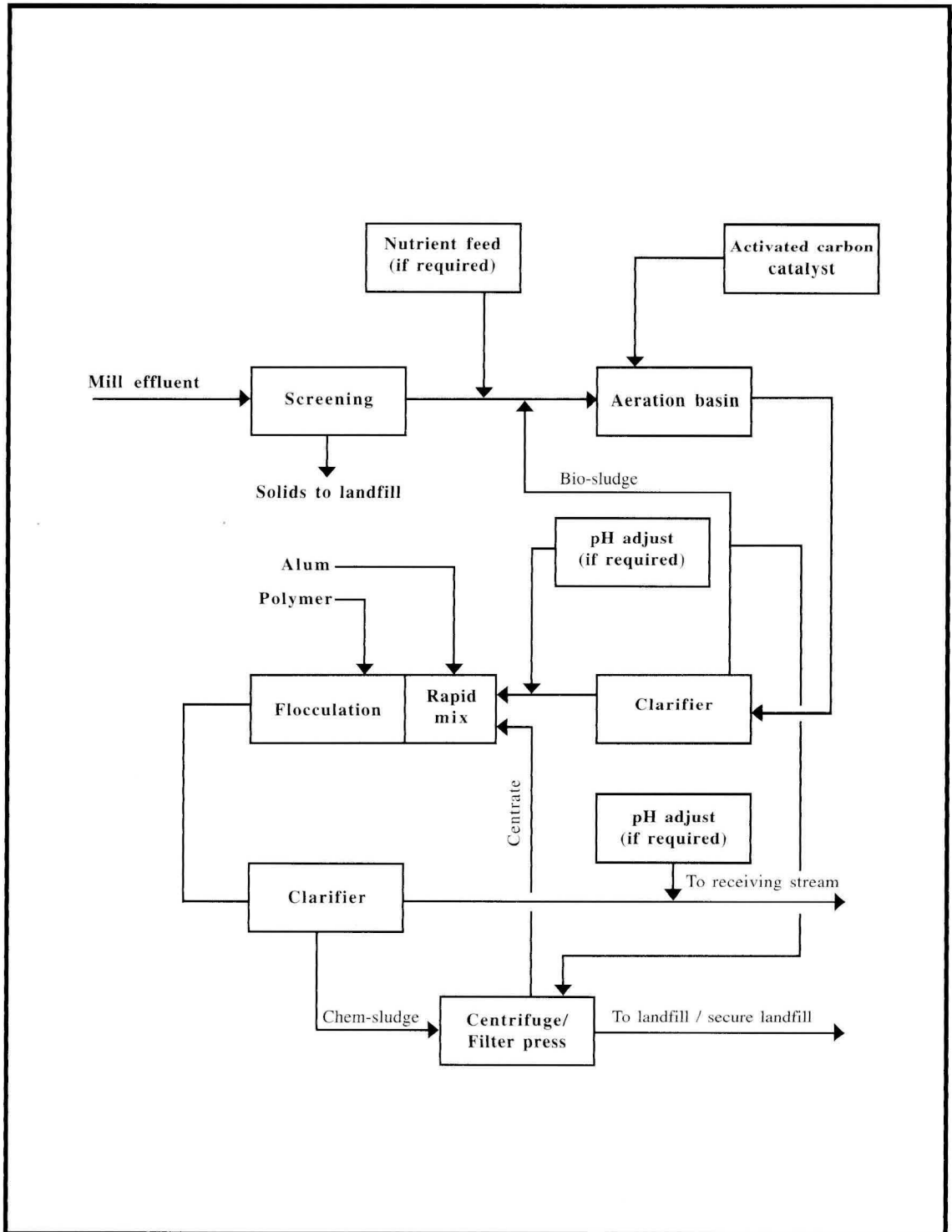


Figure 11 : Typical Treatment Technology for Combined Wastewater from Dyeing, Bleaching, Printing and Finishing Processes

Foaming problems are common in the aeration basin and cannot always be controlled by conventional water sprays. Powdered activated carbon or a defoaming agent can be introduced to reduce or eliminate the foaming. Though not effective as a defoamer, activated carbon will also act as a catalyst which improves BOD, COD and colour removal efficiencies of the biological system.

- Chemical Treatment:

With biological treatment alone, the desired levels of BOD and COD removal are difficult to achieve consistently. Chemical treatment will serve to remove additional BOD, COD and TSS. Common coagulants used are alum and polymer. Optimum treatment may require lowering the pH. If so, final pH re-adjustment may also be necessary before discharging the treated effluent.

- Sludge Treatment and Disposal:

Biological and chemical sludges may be dewatered using a solid bowl centrifuge or filter press. The sludge may be pre-conditioned with a cationic polymer. The centrate or filtrate is returned to the rapid-mix flocculation tank for treatment. With the current use of environmentally-friendly dyes in the textile industry, the sludge from the centrifuge or filter press may be suitable for disposal in an ordinary landfill. However, toxicity has to be ascertained and if found to be toxic, disposal has to be at a secure landfill such as provided in the scheduled waste treatment facility of Kualiti Alam at Bukit Nenas, Negeri Sembilan.

### 6.2.1.3 Knitting Mills

Knit fabric finishing operations are also similar to woven fabric finishing, except that sizing/desizing and mercerizing operations are not required for knit fabric finishing. Instead, knit yarn is treated with lubricants rather than with the starch or polymeric sizes used for woven goods.

Lubricants (knitting oil) are applied to knitting yarn and generally contain:

- Mineral oil;
- Vegetable oil;
- Synthetic ester type oil; or

- Waxes; and may also contain
- Anti-static agents, anti-oxidants, bacteriostats and corrosion inhibitors.

It is important to note that:

- Knitting oils are also injected into the needles of knitting machines to lubricate and lower the temperature of the needles;
- Knitting oils present in knit greige goods are readily emulsified or soluble in water and easily scoured or washed-out before dyeing;
- Mineral and scour detergents in the effluent are generally not readily biodegradable;
- Emulsified oils in knit fabric finishing plants at high concentrations will interfere with the biological process and COD removal;

**Figure 12** is a process flow diagram representing a typical wastewater treatment technology for knitting mills to meet the effluent standards stipulated in the Sewage and Industrial Effluents Regulations. This treatment technology is for treating wastewater containing high concentrations of emulsified oil. It essentially consists of chemical treatment and dissolved air flotation followed by biological treatment in an activated sludge system.

Physical treatment using the ultrafiltration technique can concentrate oil from its emulsified form and produce a permeate with less than 5 mg/l residual oil and reusable as process water. The concentrate (less than 10% by volume) may be dewatered further by the addition of a de-emulsifier and the concentrated oil fraction separated-out by air floatation. The concentrated oil has a potential use as a boiler fuel.

Where the emulsified oil content is less than about 100 mg/L and it is not expected to pose a problem to biological treatment, then treatment involving biological and chemical methods (i.e. without air flotation) are sufficient as per the treatment process flow diagram shown in **Figure 13**.

The typical treatment facility inclusive of dissolved air floatation consists of the following treatment units:

- *Screening:*

An 80-mesh screen may be used to remove fibre, lint and solids before the wastewater enters the subsequent treatment processes.

- Equalisation:

Equalisation of the raw wastewater is desirable as chemical dosage and pH adjustments are sensitive to waste characteristics. Adequate mixing is important in equalisation to prevent septic conditions and solids deposition.

- Chemical Treatment:

Coagulation is typically accomplished by using alum and a polyelectrolyte. pH adjustment may be necessary to provide proper reaction between alum and emulsified oil. After forming the floc, the pH may have to be re-adjusted to meet effluent standards.

- Dissolved Air Flotation:

Dissolved air floatation is used to separate the chemically coagulated floc. Flotation skimmings and settled sludge are further dewatered. Clarified effluent is introduced into the biological treatment system.

- Biological Treatment:

Activated sludge extended aeration is used with 3 to 5 days retention time. Aqueous or anhydrous ammonia is added to serve as nitrogen source. Foaming problems are not anticipated unless a large percentage of fibre processed is cotton.

- Sludge Treatment and Disposal:

Centrifugation or filter pressing may be used for sludge dewatering of both chemical and biological sludge. The sludge are fed separately to the centrifuge unit/filter press and conditioned with a cationic polymer. The centrate/filtrate is returned to the flocculation basin. Final disposal of sludge from the centrifuge/filter press in an ordinary landfill is acceptable, if it is ascertained that the sludge is non-toxic. If the sludge is toxic it has to be sent to a secure landfill at an off-site scheduled waste treatment plant such as Kualiti Alam.

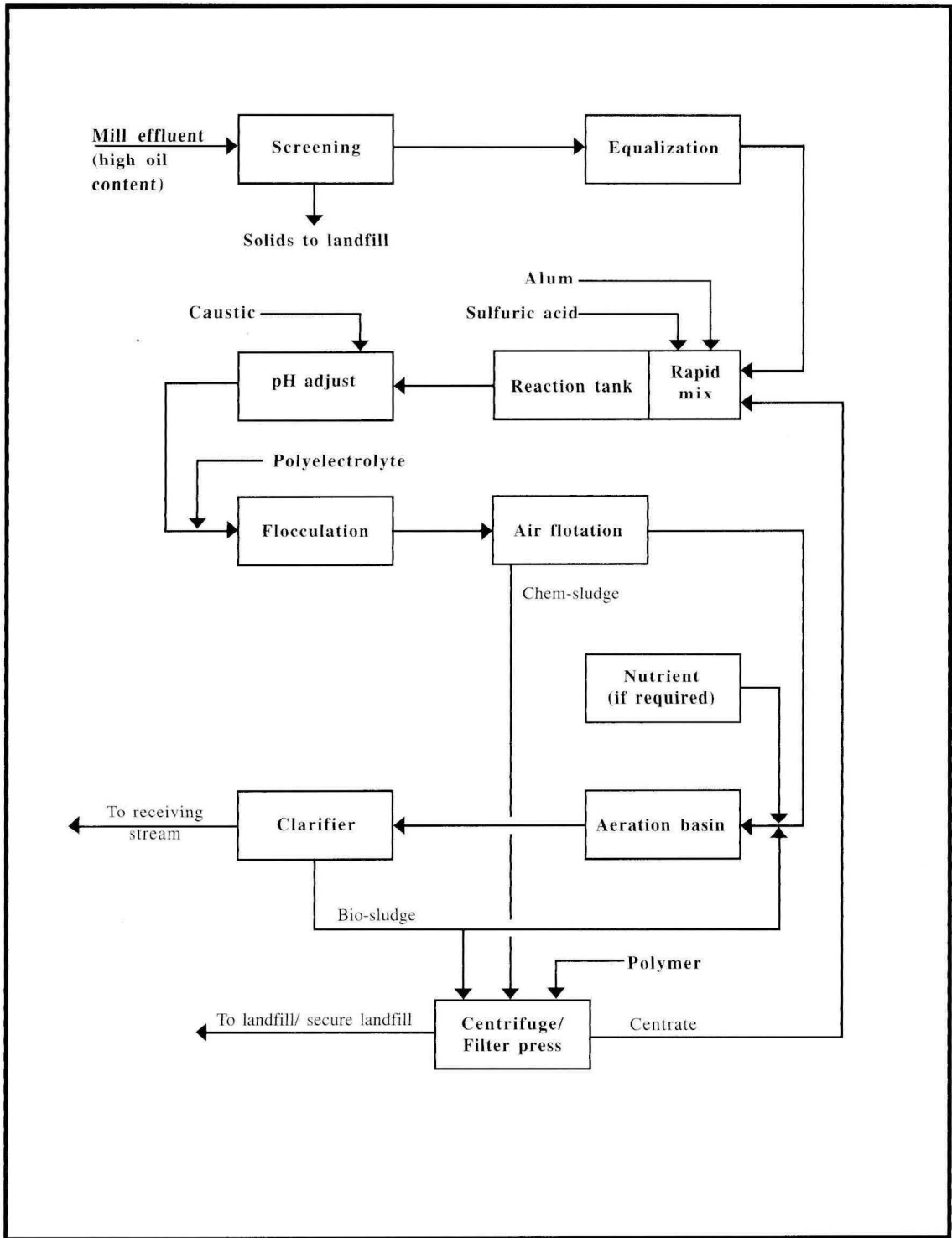


Figure 12 : Typical Treatment Technology for Combined Wastewater from Knitting Mills with High Emulsified Oil Content

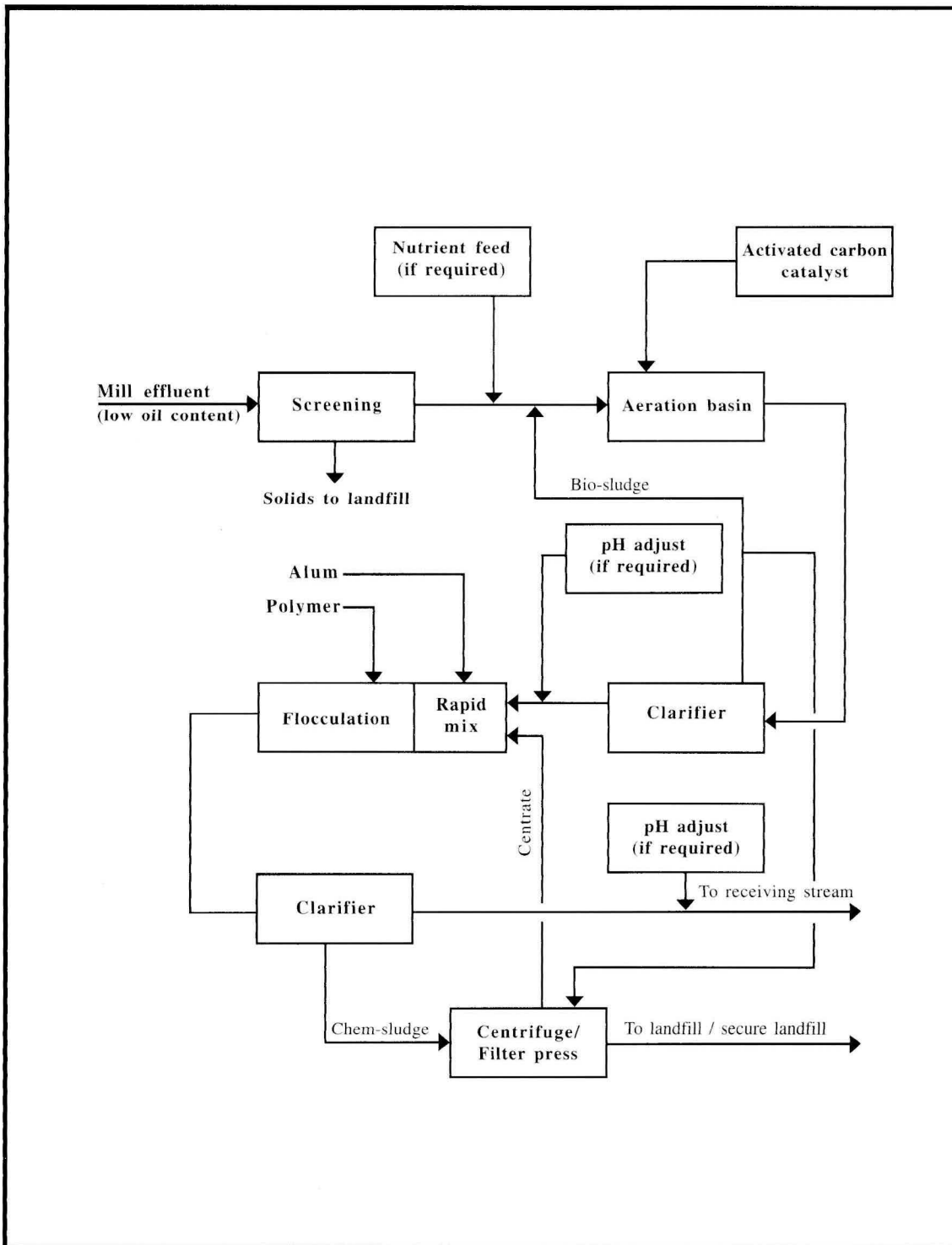


Figure 13 : Typical Treatment Technology for Combined Wastewater from Knitting Mills with Low Emulsified Oil Content

#### 6.2.1.4 Synthetic Fibre Mills

Synthetic fibre textile mills essentially produce synthetic fibres such as polyester and nylon from organic chemicals using spinning processes. The fibres are produced from chips obtained by the process of polymerisation and condensation of organic chemicals such as Purified Terephthalic Acid Ethylene Glycol for producing polyester chips and Caprolactan for nylon chips. The fibres are then converted into spin yarn and filament yarn. The operations extend also for knitting, weaving, dyeing and finishing for the production of synthetic fabric.

The wastewater treatment facility consists of screening, equalisation, sedimentation, chemical treatment, air floatation, biological treatment and sludge handling/disposal.

### 6.2.2 Wastewater Treatment Systems in Selected Textile Mills in Malaysia

Applications of the principles of treatment discussed in Section 6.2.1 can be seen in the different treatment systems implemented by selected textile mills in Malaysia, as follows:

- Hing Yap Knitting Industries Berhad, Taman Kepong, Kuala Lumpur
- Ramatex Textiles Industrial Sdn.. Bhd., and
- Hualon Corporation (M) Sdn. Bhd., Melaka

A manufacturing profile of each of the above textile mills, together with descriptions and process flow diagrams of their respective wastewater treatment systems are presented in *Annex G*.

## 6.3 AIR EMISSION CONTROL

### 6.3.1 General

The textile industry, by the nature of its operations, is not a major source of air pollution. With the exception of steam-generation, emissions from textile processes generally fall into the following four categories:

- Oil and acid mists
- Solvent vapours
- Airborne dust and lint
- Odorous substances

A wide variety of equipment are available for abatement and control of the various types of air emissions produced by textile processes. These may be divided into three broad categories as follows:

- Those that destroy the pollutant, namely incinerators;
- Those that collect it in a relatively concentrated “dry” form such as the cyclone separators, bag filters, electrostatic precipitators, and absorption systems; and
- Those that wash it from the exhaust into water or some other collecting liquid such as the wet scrubber.

### 6.3.2 Elimination of Oil and Acid Mists

When textile materials are subject to heat treatment above 200°F, some volatilisation of oils, waxes, plasticisers etc., that are present on or in the material occurs. The mist is formed when the vapour-laden air is cooled to about 45 °C to 70 °C, causing recondensation of these low vapour pressure organic compounds. The mist consists of fine droplets of a diameter range of 0.1 to 1 micron, with 75% of the droplets being less than 0.5 micron in diameter.

Feasible abatement techniques include:

- Process modification
- Incineration
- High energy scrubbing
- Electrostatic precipitators
- High efficiency fibre mist eliminators
- High velocity air filters

The techniques applicable to oil mist elimination apply for the most part to elimination of acid mists as well, though special consideration must be given to the corrosive nature of the mists. Incineration is practical only if the mist contain no inorganic acids, such as  $H_2SO_4$ , HCl, HF etc., or halogenated organic acids such as trichloroacetic acid. Mineral acids are unaffected by incineration, and halogenated organic acids are merely oxidised to the corresponding mineral acids. Specially designed electrostatic precipitators, generally lead-lined can be used successfully. High efficiency mist eliminators can also be used effectively if constructed of acid-resistant materials.

### 6.3.3 Solvent Vapours

Following each process in which textile materials are treated with organic solvents, the solvents are driven-off generally by hot air drying, and then are recovered by condensation followed by adsorption in activated charcoal.

### 6.3.4 Airborne Dust and Lint

Of the various types of particulate air emissions, the most undesirable is cotton dust which has the potential for causing byssinosis - a serious respiratory disease.

The dust and lint abatement techniques include the following:

- Pre-cleaning of the incoming cotton by continuous steam cleaning apparatus;
- Use of plenums on cards, stretch breakers etc., to remove airborne dust and fly as they are created followed by vacuum-cleaning, especially at points where the sliver or roving goes through orifices or around turns;
- Use of low-energy scrubbers for removal of lint and coarser airborne dust, such as cyclone scrubbers and spray towers;
- Filters to remove lint and coarser airborne dust, use of automatic self-cleaning filters for fly removal in high fly areas.

### 6.3.5 Odours

Common textile processes and substances that cause odour problems include aqueous polyester-dyeing, where most of the carriers have extremely annoying odours at low concentrations. Other sources of odour are:

- Defoamers used in some dyeing and printing processes;

- Sulphur-dyeing of cotton and cotton blends;
- Reducing or stripping dyes using hydrosulfites;
- Bonding, laminating and back-coating operations and bleaching with chlorine dioxide.

Abatement techniques include:

- Process or chemical substitution and house-keeping improvement
- Dilution
- Masking or modification
- Scrubbing
- Dry adsorption
- Incineration

## **6.4 DISPOSAL OF HAZARDOUS WASTES**

Hazardous wastes from textile mills generally consist of spent solvents, wastewater treatment plant sludges, empty containers used for packing chemicals, and spills clean-up materials. These are disposed of at off-site hazardous waste treatment facilities. Sludges that are not toxic may be disposed of at ordinary landfills.

## **6.5 NON-HAZARDOUS SOLID WASTES**

Non-hazardous waste consisting of fabric and yarn scraps, off-specification yarn and fabric packaging waste, cotton trash, leaves and stems can be disposed of at ordinary landfills.

## **6.6 OCCUPATIONAL HEALTH AND SAFETY CONCERNS**

Occupational health and safety concerns in textile mills generally relate to excessive noise emission from weaving and knitting machines, air emissions from textile materials including formaldehyde, and odour-causing amine compounds. Occupational exposure to air emissions can be effectively controlled through proper factory ventilation as well as application of local exhaust ventilation for specific equipment that emit gases or vapours. Other abatement techniques include the use of personal protective devices such as ear guards or ear muffs, gas and dust masks, and protective clothing. Other preventive strategies are discussed under the Section 7 on Pollution Prevention and Cleaner Production Approach.

## **7.0 POLLUTION PREVENTION AND THE CLEANER PRODUCTION APPROACH**

### **7.1 INTRODUCTION**

In general, it has become increasingly clear that a new approach to prevent industrial pollution is required, especially in countries like Malaysia that are experiencing rapid economic and industrial growth. The new approach, which is emerging, incorporates the concepts of sustainable development and cleaner production, together with an emphasis on good management practices. This pollution prevention and cleaner production approach is inherently beneficial to the industry as it enables resource conservation and enhanced resource utilisation.

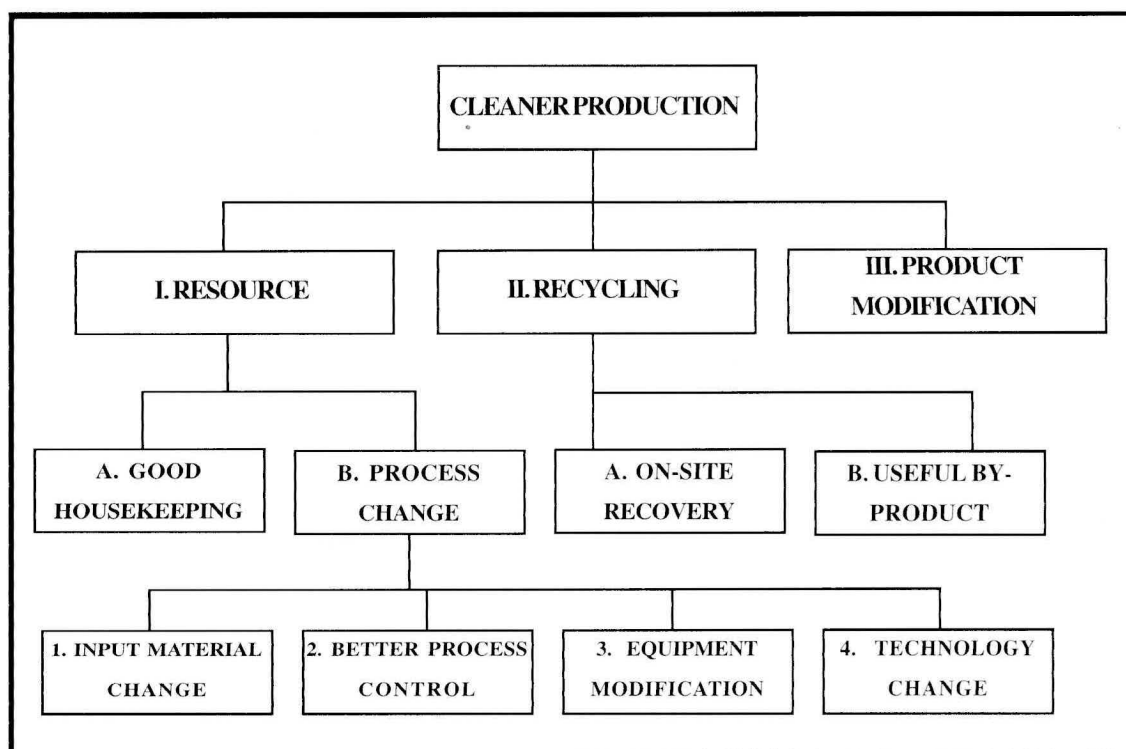
Cleaner production can be defined as “the continuous use of industrial processes and products to prevent the pollution of air, water and land to reduce waste at the source and to minimise risks to human population and the environment (UNEP, 1994). This is best practised by reducing the generation of waste at the source itself. After exhausting the source reduction opportunities, in the second step, attempts should be made to recycle the waste within the unit. Finally, attempt should be made to modify or reformulate the product itself so as to be able to manufacture it with minimal waste generation. The types of techniques available in these areas are given in **Figure 14**.

The benefits of cleaner production have been clearly demonstrated through several DANCED-supported industrial demonstration projects involving SIRIM and also in the Malacca River Rehabilitation Project, as well as by the experiences of several countries worldwide. The cleaner production approach can minimise the need to make trade-offs between economic growth and environmental protection, between workers’ safety and productivity, and between consumers’ safety and competition in international markets. The cleaner production approach is a ‘win-win’ strategy. It protects the environment, the consumer and the worker while improving industrial efficiency, profitability and competitiveness. The savings obtained can be utilised to implement cost-effective end-of-pipe technology to comply with the emission standards prescribed in the respective effluent control regulations.

### **7.2 CLEANER PRODUCTION IN THE TEXTILE INDUSTRY**

#### **7.2.1 The Cleaner Production Approach**

Most of the pollution prevention activities in the textile industry have been focused on reducing chemical and water use, reusing process water and reducing all solid waste forms - pallets, cardboard, etc. and fugitive emissions. This Section describes some of the pollution prevention opportunities for textile factories.



**Figure 14: Overview of Cleaner Production Techniques**

Waste minimisation thus includes the following eight techniques (or approaches) :

1. Good housekeeping: appropriate provisions to prevent leaks and spills (such as preventive maintenance schedules and frequent equipment inspections) and to enforce the existing working instruction (through proper supervision, training etc.)
2. Input material change: substitution of input materials by less toxic or renewable materials or by adjunct materials with a longer service lifetime.
3. Better process control: modification of the working procedures, machine instructions and process record keeping in order to run the processes at higher efficiency and lower waste and emission generation rates.
4. Equipment modification: modification of the existing productive equipment and utilities - for instance by the addition of measuring and controlling devices - in order to run the processes at higher efficiency and lower waste and emission generation rate.
5. Technology change: replacement of the technology, processing sequence and/or synthesis pathway in order to minimise waste and emission generation during production

6. On-site recovery and reuse: reuse of the wasted materials in the same process or for another useful application within the company.

7. Production of useful by-product: modification of the waste generation process in order to transform the wasted material into a material that can be reused or recycled for another application outside the company.

8. Product modification: modification of the product characteristics in order to minimise the environmental impacts of the product during or after its use (disposal) or to minimise the environmental impacts of its production.

### 7.2.1.1 Quality Control for Raw Materials

Textile companies can reduce waste by working with suppliers and developing purchasing codes that commit companies to using less polluting raw materials. A raw material quality control program is essential to prevent the ordering and use of untested materials and can be implemented by establishing specific and appropriate purchasing, packaging and inventory control policies.

Benefits of such programmes include:

- Decreased production of off-quality goods;
- Less rework; and
- Increased product consistency.

Companies can also control raw materials quality by pre-screening and testing shipments as they are received. Pre-screening provides facilities with opportunities to determine chemical and mechanical alternatives, proper chemical use, and training and proper disposal and treatment methods.

The steps to be taken in this regard are described below.

- Adopt environmentally responsible purchasing policies to obtain less-polluting raw materials:
  - Adopt purchasing policies that restrict the use of hazardous chemicals as a way to reduce waste.

- Work with vendors to set acceptable guidelines for the purity and content of chemicals, especially chemicals that are typically of unknown composition, e.g. solvents, dye carriers and dyes.
  
- Perform test on raw materials shortly after receipt:
  - Pre-screen raw materials to determine interactions with processes, substrates and other chemicals.
  - Determine environmental effects, proper handling and emergency procedures for chemicals; this can enable early detection of mislabeled drums and reduce occurrence of costly production mistakes due to untested chemicals being processed.
  
- Establish a protocol for incoming chemical quality control:
  - Mark the date the container was opened.
  - Checking pH, viscosity, density, conductivity and colour.
  - Compare data with previous history and vendor's standard values.
  - Enter data on a control chart for display, maintain records and review data with the vendor.
  - Check environmental data including whether the chemicals are listed under the schedule of hazardous wastes or list of banned chemicals, and whether the waste streams containing such chemicals should be segregated to facilitate treatment and disposal.
  
- Purchase raw materials in returnable containers:
  - Work with vendors to ensure that packages can be returned without being cleaned on site.
  - Off-site cleaning transfers chemical wastes back to the production facility, which is better able to handle such wastes.
  - Chemical specialities should be purchased in returnable, reusable containers.
  - Purchase of chemicals in bulk containers and intermediate bulk containers eliminates waste packing materials and reduces spillage, handling costs and worker exposure to chemicals.
  - Fugitive emissions can also be reduced by bulk storage and transferring these chemicals by closed conveyor system to the process line.

### 7.2.1.2 Chemical Substitution

Textile manufacturing, being a chemically intensive process, a primary focus for pollution prevention is substitution of polluting chemicals with less-polluting chemicals. Chemical substitution can minimise chemical waste and the need for costly pollution abatement and control equipment. Some of the specific areas of successful application of chemical substitution are summarised in **Table 7**.

In general, the following areas of chemical substitution should also be considered:

- Replacement of solvents to reduce waste, reduce costs associated with treatment systems, and increase worker safety.
- Some textile chemicals that can be substituted include desizing agents, dyes and auxiliaries.
- Replacement of chemicals in some processes with mechanical or other non-chemical treatment methods. In many cases, offensive chemicals should be adjusted, substituted or removed from a process instead of adding chemicals to offset undesired effects of these chemicals, e.g. by using environmentally friendly dyes, water could be used for washing machinery instead of solvents. Chemical biocides for disinfecting cooling towers should be substituted with the use of ultraviolet light where possible (a pay-back period of 11 to 18 months is achievable through savings in chemical usage).

### 7.2.1.3 Process Modification

Process changes that optimise reactions and use of raw materials can be used to prevent pollution. Modifications may include improved process control systems or changes in chemical application methods.

Process modifications should also be directed at minimising energy consumption wherever possible. The following are among the significant process modifications in the textile industry directed at waste minimisation and resource conservation:-

- *Use of low-liquor ratio dyeing machines:*

Mills have been moving towards reduced bath ratio dyeing. Bath ratio is defined as the weight of goods (or fabrics) divided by the weight of the bath. Some chemicals, such as salt and lubricants, act on the dye bath, whereas others, such as dyes and softeners, act on the fabric. In each case, these chemicals are factored into the weight of the bath or the weight of the fabric.

Table 7: Suggested Chemical Substitutions

TEXTILE PROCESS	CHEMICAL TO BE SUBSTITUTED	SUGGESTED SUBSTITUTE CHEMICAL	REMARK
Preparation	<ul style="list-style-type: none"> <li>Existing washing agents</li> <li>Bleaching chemicals: Sodium hypochlorite, sodium chlorite, and potassium permanganate</li> </ul>	<ul style="list-style-type: none"> <li>Newly available washing agents</li> <li>Hydrogen peroxide</li> </ul>	<ul style="list-style-type: none"> <li>To increase wash efficiency, decrease water consumption and improve fastness of reactives.</li> </ul>
Desizing	<ul style="list-style-type: none"> <li>Desizing enzymes</li> </ul>	<ul style="list-style-type: none"> <li>Hydrogen peroxide</li> </ul>	<ul style="list-style-type: none"> <li>Improve cost-effectiveness. This method produces carbon dioxide and water as wastes instead of hydrolysed starch which increases BOD load.</li> </ul>
Dyeing	<ul style="list-style-type: none"> <li>Copper-based dyes</li> <li>Dye-fixation reactives</li> <li>Low temperature dye-fixation reactives</li> <li>Phosphates (auxiliary chemical)</li> </ul>	<ul style="list-style-type: none"> <li>Copper-free dyes</li> <li>Improved dye-fixation reactives</li> <li>High temperature dye-fixation</li> <li>Reactives</li> <li>Acetic acid and EDTA</li> </ul>	<ul style="list-style-type: none"> <li>Reduce metal loading of wastewater, although this may sacrifice the range of colour shades that can be achieved.</li> <li>Reduce unreacted and degraded dye in spent baths and improve the reuse potential of washwater.</li> <li>For simultaneous application of disperse and reactive dyes. This reduces energy use and eliminates the caustic bath required after disperse dyeing.</li> <li>Reduce phosphorous load in wastewater.</li> </ul>

The following are the principal observations and benefits:

- Low bath ratio dyeing can save energy and reduce chemical use, because energy and chemical use depend on bath volume.
- Jet dyeing and package dyeing are commonly used for low bath ratio dyeing.
- Typical bath ratios for exhaust dyeing methods are as follows: beck (17:1); jet (12:1); jig (5:1) and package (10:1). Pad batch methods have a 1:1 bath ratio.
- Ultra-low liquor bath ratios can also reduce cycle times due to quick machine drains and fills and rapid heating and cooling.
- Ramatex Berhad has installed in a textile facility in Batu Pahat, Johore, the air-flow dyeing machine with a bath ratio of 3:1, with several benefits such as less wastewater for treatment and savings on dye use. The pay back period is less than 3 years.

- Use of pad batch-dyeing methods:

The principal observations and benefits of pad batch-dyeing are:-

- Use of pad batch (cold) dyeing for cotton, rayon and blends conserves energy, water, dyes and chemicals, labour and floor space.
- Pad batch dyeing methods do not require salt or chemical specialities, so this method can be a good way for facilities to reduce waste and save money.
- While pad batch dyeing is a cost-effective way for facilities to apply reactive dyes to cotton and rayon, this method may not achieve the desired final fabric properties for all cottons.
- Pad batch dyeing is also not appropriate for dyeing synthetic fabrics.

In pad batch dyeing, prepared fabric is impregnated with liquor (water and process chemicals) containing premixed fibre reactive dyestuff and alkali. Excess liquid is squeezed out using a mangle. The fabric is then batched onto rolls or into boxes and covered with plastic film to prevent absorption of CO<sub>2</sub> from air or evaporation of water. The fabric is then stored for two to twelve hours. Pad batch dyeing is more flexible than continuous dyeing methods. The flexibility of pad batch equipment and the use of water-soluble dyes minimises cleaning operations.

- Use of countercurrent washing to reduce water use:

The principal observations and benefits of pad batch-dyeing are:-

- Counter current washing decreases wastewater from preparation processes.
- Counter current washing is simple, easy to implement and relatively inexpensive.
- Counter current washing is a technique to reuse the least contaminated water from the final wash for the next-to-last wash and so on until the water reaches the first wash stage. Wash-water from the first stage is discharged.
- Counter-current washing equipment can be retrofitted to any multistage continuous washing operation whether it is installed for different fabrics or for dyeing, printing or preparation operations.
- Flow optimisation is usually a good pollution prevention activity to run in conjunction with counter-current washing.

**Table 8** shows typical water-savings based on the frequency of water reused.

**Table 8 : Typical Water Savings Using Counter-current Washing**

Number of Washing Steps	Water Savings (%)
2	50
3	67
4	75
5	80

Source: *Best Management Practices for Pollution Prevention in the Textile Industry*, US EPA, Office of Research and Development, 1995.

- Optimisation of process conditions:

Mills can reduce waste and increase production efficiency by optimising process conditions, such as temperature and time. Mills can also modify the processes themselves to increase the efficiency. For example, by extending the length of time fabrics were dyed by 15 minutes, dyeing exhaustion is improved, resulting in 60% reduction in BOD and COD; this resulted in considerable savings.

- Combine processes:

Mills can reduce waste and increase production efficiency by combining operations. For instance combined scouring and bleaching can save energy and water. Cold pad-batch methods can be used at room temperature for long desizing, scouring and bleaching cycles. The single-step cold batch method of desizing minimises energy and water use and maximises productivity.

#### 7.2.1.4 Process Water Reuse and Recycle

Recovery, recycling and reuse can be effective tools for minimising pollutant releases to the environment. By recovering solvents and raw materials, textile mills can reduce raw material costs and can reduce pollution with little modification of existing processes. Water is widely used in the industry for processes ranging from dyeing to preparation and finishing. Raw materials such as unexhausted dyestuff and additives can also be recycled. Reuse and recycling are excellent ways for facilities to save money, reduce waste and save energy.

- Reuse of dye baths:

Dye bath reuse is the process of analysing, replenishing and reusing exhausted hot dye baths to dye further batches of material. Although, not applicable to all processes, in some processes, dye bath reuse can reduce pollution concentrations and effluent volume and generally requires a low capital outlay for laboratory and support equipment, machine modifications, tanks, pumps and pipes. Operating cost is also low. It also saves on the cost of dyes, chemicals and energy. Dye bath reuse principles can also be applied to bleaching baths.

Dye bath reuse comprises four basic steps:

- The first step is to save the exhaust dye bath. The dye bath is pumped to a holding tank, the product is rinsed in the same machine in which it was dyed, and then the product is removed and the dye bath returned to the dye machine.

- The product can also be removed from the exhausted dye bath and placed in another machine for rinsing.
  - The dye bath is then analysed for residual chemicals. Unexhausted dyestuffs must be analysed to determine the exact quantities remaining in the dye bath to ensure proper shade in the next dyeing cycle. This analysis can be performed using a spectrophotometer and guidelines based on specific production experience.
  - The dye bath is then reconstituted by adding water, auxiliary chemicals and dyestuffs. If properly controlled, dye baths can be reused for 15 or more cycles, with an average of 5 to 25 times.
- *Reuse of rinse baths:*
    - Wet processing consumes a large amount of water from rinsing of textiles.
    - Preparation and finishing water also can be reused.
    - In a yarn finishing company, recycling drastically reduced wastewater volume, soda ( $\text{Na}_2\text{CO}_3$ ) and caustic consumption. The rinse bath was reused three times following mercerizing rather than dumping the bath water after each use. The spent rinse water was then processed in an evaporator and concentrated caustic was reused in mercerising. The facility reduced suspended solids by 80%, COD by 55% and the mercerising soda in the wastewater by 70%. Corresponding reductions in hydrochloric acid used to neutralise the effluent were also made. The investment in the new equipment resulted in considerable annual savings with a pay-back period of less than 1 year.
    - In another case, holding tanks were installed for bleach bath reuse. The bath was reconstituted to correct strength after analysis by titration. BOD decreased by 50%. Water use also decreased.

#### 7.2.1.5 Volume Reduction

Volume reductions include techniques to separate problem wastes and recoverable wastes from the total waste stream. These techniques are usually used to increase recoverability or reduce the volume of waste generated. The available techniques used range from simple segregation of wastes at the source to complex concentration technology.

Segregation of wastes is usually a simple and economical technique for waste reduction. By segregating wastes at the source of generation, and handling the hazardous and non-hazardous wastes separately, waste volume and management cost can be reduced significantly. Additionally,

the uncontaminated and undiluted wastes may be reused in the production process or may be sent off-site for recovery.

Segregation techniques are applicable to a wide variety of waste streams and industries and usually involve simple changes in operational procedures. A common technique is to collect and store washwater or solvents used to clean process equipment (such as tanks, pipes, pumps or printing presses) for reuse in production processes.

#### 7.2.1.6 Equipment Modification

An additional method to reduce waste is to modify, retrofit or replace equipment. Some facilities are switching to computer-controlled dyeing systems, which analyse the process continuously and respond more quickly and accurately than manually controlled systems. In many cases, modifying equipment can provide source reduction by reducing ratio of water and chemicals to textile goods.

- Installation of automated dosing systems and dye machine controllers:

The use of automated process control equipment has had a significant effect on the textile industry:-

- Chemical dosing systems can be optimised to deliver the right amount of the right chemical at just the right time.
- These systems improve the efficiency and reliability of chemical reactions in the dye bath ensuring more consistent and reproducible results
- These systems reduce the tendency to overuse environmentally harmful chemicals, which may pass through treatment systems unreacted or may react to produce undesirable by products.
- Dosing systems also reduce handling losses and equipment clean-up.
- Dye machine controllers are a good way to increase control over processes.

- Use of continuous horizontal washers:

Continuous horizontal washers can conserve energy and water as follows:-

- Horizontal washers work for woven fabrics in a narrow weight range.

- These washers operate by spraying clean washwater on the top (final) pass of fabric as it makes a series of horizontal traverses upward in the machine.
  - The unprocessed fabric enters at the bottom traverse and the water enters at the top.
  - These vertical spray washers reduce water and energy use as well as improve quality and captured suspended solids for dry disposal.
  - Vertical double-laced washers with serpentine counterflow may be more versatile and achieve better results than continuous horizontal washers.
- Use of continuous knit bleaching ranges:
    - Many textile companies use continuous knit bleaching ranges to reduce water consumption.
    - These ranges consume less water, energy and chemicals than batch preparation knitting equipment.
    - The new machines feature inherent countercurrent water use and improvements over old rope bleaching units, including better fabric transport, better chemical metering systems and better filtering of the baths.

#### 7.2.1.7 Good Operating Practices

Companies can improve production efficiency and maintain low operating cost by incorporating pollution prevention codes into their management procedures. These codes can include:

- A written commitment by senior management to ongoing waste reduction at each of the company's textile facilities and to include pollution prevention objectives in research and new facility design.
- Establishing training and incentive programmes and improving record-keeping to prevent pollution without changing industrial processes.
- Good-housekeeping practices to help minimise wastes from maintenance and off-specification materials.
- Water use reduction through minimising leaks and spills, proper maintenance of production equipment and identification of unnecessary washing of both fabric and equipment.

In particular, textile mills should adopt the specific good operating practices described below.

- *Schedule dyeing operations to minimise machine cleaning:*

In dyeing operations, start-ups, stop-offs and colour changes often result in losses of substrate, potential off-quality work and chemically intensive cleanings of machines and facilities; the following are important considerations:

- Proper scheduling of dyeing operations significantly reduces wastes generated by textile mills.
- A well-planned dyeing schedule can reduce the number of machine cleanings required and the pollution load that results from start-ups, stop-offs and colour changes.
- Reduced machine cleaning therefore significantly reduces the waste load generated by textile facilities.
- Minimising machine cleaning may not be possible in some cases because of the need for flexible schedules to meet the changing market demands.
- Ultimately, the need for dye machine cleaning is contingent upon the sequencing of colours in the dyeing process. The ideal sequence requiring the least amount of machine cleaning is to run the same colour repeatedly on a particular machine. The second best way is to group colours within families (red, yellow, blue) and then run the dyes within one colour family from lighter to darker values and from brighter to duller chromas.

- *Optimise cleaning practices:*

- Modifying equipment's cleaning practices can reduce wastewater discharges and reduce solvent use.
- Substituting cleaning solvents with less toxic solvents, or use of water-soluble dyes to completely avoid the use of solvents for machine cleaning, reduces hazardous waste generation and simplifies wastewater treatment.

- *Optimise housekeeping practices:*

- Good inventory management can reduce waste by using all materials efficiently and reducing the likelihood of accidental releases of stored material.

- Housekeeping and work habits of chemical mixers can account for 10 to 50% of a textile mill's total effluent load in BOD, COD, metals and organic solvents. Improvements in housekeeping generally costs little or nothing, and can improve employee morale, workplace safety and product quality.
  - Designating a materials storage area, limiting traffic through the area and giving one person responsibility to maintain and distribute materials can also reduce materials use and contamination and dispersal of materials.
- Adopt worker training programmes:
    - Companies should establish safety procedures for receiving, storing and mixing chemicals and implement worker training programmes.
    - Workers should be informed of the environmental impacts of chemicals especially those most harmful to the environment, and be trained in proper procedures in handling these chemicals.
    - Training should also include correct procedures for pasting, dissolving and emulsifying of chemicals. These procedures should be subject to auditing and record keeping.
    - Policies regarding receipt, storage and mixing should be established.
- Cost accounting practices:
    - Cost accounting practices include programmes to allocate waste treatment and disposal cost directly to the department or group that generate waste, rather than charging these costs to general company overhead accounts.
    - The department or group that generates the waste will become more aware of the effects of their treatment and disposal practices, and have financial incentive to minimise their waste.

### 7.2.1.8 Specific Waste or Waste Problems

The specific pollution issues which traditional waste treatment techniques are insufficient to address include:

- Colour
- Salt
- Toxic air emissions
- Improved treatability of waste
- Metals
- Aquatic toxicity

For these issues, pollution prevention is important and in many cases represents the only long-term alternative.

- Colour:

Colour in effluent from textile dyeing and printing is being increasingly regulated and is widely recognised as a compliance problem that must be addressed through pollution prevention. The effluent from most textile dyeing operations generally has a dark reddish-brown colour that is aesthetically displeasing when discharged to receiving waters.

Although, many methods of colour removal exist, none work satisfactorily in every case. Because of the difficulties and expense in treating colour, the best approach for minimising colour discharge is pollution prevention.

A mill can take many actions to reduce colour in wastewater, each involving the use of process optimisation to achieve the highest possible fixation. The strategies for achieving high fixation vary depending on whether batch or continuous dyeing is performed. Batch dyeing achieves better fixation due to the combined effects of exhaustion and fixation, while continuous dyeing depends on fixation only.

The main problems with colour in effluent result from cotton dyeing. In batch dyeing, the most important control measures are to:

- Ensure a good cloth preparation
- Use a low bath ratio
- Select high affinity dyes
- Optimise pH and salt, if used, for each recipe
- Use proper time-temperature profile relationships
- Avoid auxiliaries that retard or reduce exhaustion
- Minimise the use of auxiliaries and surfactants
- Avoid adding more chemicals (e.g. defoamers) to offset the undesired side-effects of other chemicals in favour of non-chemical alternatives (e.g. procedural or mechanical remedies, or changing the dye solution or the product itself).

As in batch dyeing, the key to minimising colour discharges in continuous dyeing or printing operations is to maximise fixation, which occurs mainly through steam, thermo-fixation or chemical agents. The proper dwell time and temperature in the steamer or thermo-fixation oven is essential. Also, the presence of air in steamers can oxidise vat dyes prematurely and lead to excessive wash-off.

Also, making up only the amount of dye solution or print paste actually needed is equally important, so that no extra solution or paste remains to be discarded at the end of the run. Discard and pad dumps are the main source of colour in washwater from continuous dyeing and printing.

Printing is an inherently messy operation and the control measures to minimise problems of colour in the final effluent discharge, include:

- Good housekeeping practices due their substantial bearing on overall colour discharges.
- Paste handling and cleaning of mixers, homogenisers, screens and squeegees should be closely controlled.
- Drums of print paste or empty drums of chemicals should not be washed out into the drain. Residues should be drained only into the next drum to be opened. If paste is left over, it should be reused or added to when making up a future colour recipe. If using leftover paste in a future recipe is impossible, the paste should be scooped up, dried and then land-filled as a solid material.

The following work practices in the colour kitchen are part of an effective pollution prevention strategy:

- Use of intermediate bulk containers
- Dry capture (vacuum)
- Avoiding powder spills
- Minimising washup by using different dippers for each chemical or using automatic chemical dispensing.

- *Discharge of Salt:*

Many types of salt are either used as raw materials or produced as by-products of neutralisation or other reactions in textile wet processes. Typical cotton batch dyeing operations use quantities of salt that range from 20-80% of the weight of goods dyed, and the usual salt concentrate in such wastewater is 2,000-3000 ppm.

The removal of salt from mixed textile wastewater is difficult and expensive by any known treatment method and pollution prevention measures for reducing salt concentration is the only practical alternative.

The salts commonly used or formed in textile processing include:

- Common salt (sodium chloride)
- Glaubers salt (sodium sulphate)
- Epsom salt (magnesium chloride)
- Potassium chloride (from potassium hydroxide)
- Others in low concentrations are also present

Although aquatic toxicities of these salts are low, their massive use in certain textile dyeing processes can produce wastewater that is well above the toxic limit.

Pollution prevention efforts, which entails trade-offs that should be understood before implementation as possible solutions, include the following:

- Use the lowest practical bath ratio in batch dyeing;
- Optimise salt use individually for each dyeing (as opposed to standard procedures used for all batches or runs);
- Consider continuous dyeing, pad-batch dyeing process alternatives;
- Minimise discards and production colour changes in continuous dyeing and printing;
- Design and make products from fibres other than cotton;
- Reuse batch dye baths;
- Ensure proper handling of dyes and fabrics;
- Select dyes that exhaust with minimum salt;
- Optimise dyeing temperature individually for recipe.

- Toxic air emissions:

Textile operations involve numerous sources of air emissions and these sources give rise to a variety of air quality issues. Although, boiler emissions of  $\text{NO}_x$  and  $\text{SO}_x$  are the main sources of high volume emissions, specific hazardous air pollutants (HAPs) emitted from coating, finishing and dyeing require control. As the amounts of these materials emitted are low in most cases, the economical approach is to reduce them as much as possible using pollution prevention practices.

The main pollution prevention methods for reducing air emissions are:

- Design and manufacture products that do not produce HAPs;
- Identify sources and quantify emissions;
- Optimise boiler operation through proper control on combustion parameters including scientific design and erection of chimneys; installation of cyclone separators for coal-fired boilers; use of low sulphur fuel to reduce sulphur dioxide flue gas;
- Pre-screen chemicals using material safety data sheets (MSDS);
- Pre-screen fibres for volatile spin finish components;

- Trap bulk storage tanks;
- Minimise or eliminate chemical auxiliaries in aqueous processes;
- Improve solvent processing operations;
- Avoid spills in bulk chemical off-loading areas;
- Investigate emerging technologies.

- Improved Treatability:

Properly designed wastewater treatment systems can remove or destroy many of the harmful contaminants in raw textile wastewater and produce an effluent that can be discharged safely to receiving waters. However, certain wastes or contaminants can interfere with the ability of biological treatment systems to operate to design specifications, resulting in system upsets and violation of permissible limits. Other contaminants are removed from the treatment system and partition into sludges, disposal of which can be difficult.

Several characteristic problems that arise from the presence of such waste include:

- Respiratory inhibition of microbiological treatment organisms
- Bulking (poor settling ability in aeration tanks)
- Sludge contamination
- Shock loading
- Pass-through of non-biodegradable materials

Pollution prevention is a useful way to reduce the above problems by minimising priority pollutants at source and eliminating shock loads.

- Metals:

The presence of metals in textile mill effluents is of concern primarily because of their toxicity to aquatic and mammal species. Metals also inhibit biological treatment operations and are difficult to remove or treat using pollution control technologies. General pollution prevention methods of reducing or eliminating metals, include:

- Careful pre-screening of all chemicals;
  - Substituting for metal-containing compounds (e.g. with non-metal dyes);
  - Improving efficiency of the process or operations by lowering chemical use while maintaining product quality objectives, perhaps by means of automation and improving management operations (e.g. better chemical handling skills);
  - Elimination of galvanised plumbing.
- Aquatic Toxicity:

The sources of aquatic toxicity include:

- Salt
- Surfactants - Alcohol ethoxylates, Alkylphenol ethoxylates, Alkylbenzene sulfonates, Alcohol ethoxysulfates
- Detergents, emulsifiers and dispersants
- Metals
- Toxic organic chemicals
- Biocides
- Toxic anions

Pollution prevention strategies for toxic chemical compounds include:

- Special handling and use procedures for the compounds described above may be necessary to keep them out of the wastewater.
- Strategies include employee training to improve awareness of the toxicity potential and handling, separate plumbing to segregate these wastes and facilitate special treatment;
- Screening procedures to identify ingredients and evaluate their potential contribution to toxicity before being put in use;
- Chlorinated solvents should be replaced with non-chlorinated types;
- Rapid and wide pH variation can also produce aquatic toxicity and should be avoided;
- MSDSs are a good, but often limited source of information on toxicity;

- Products, colours and finishes that require the use of toxic production chemicals should be identified to the designer and the consumer, and alternatives that can be produced more safely should be promoted;
- Non-process chemicals such as those used for cleaning, maintenance and weed-killing should receive special attention in terms of pre-screening evaluation, employee training as well as storage and handling, in general.

### 7.3 ADDRESSING FACTORY CONSTRAINTS

It is commonly perceived that factories are faced with various constraints in wanting to implement pollution control. Given that there are significant production cost-savings and benefits that can accrue by implementing the cleaner production measures identified in this Handbook, it appears that the factory constraints often cited are due to lack of knowledge of the available measures. Many of the perceived factory constraints can be addressed using the arguments presented in Table 9.

**Table 9: Addressing Factory Constraints**

Factory Constraints	Counter Arguments
No profit in pollution control	<ul style="list-style-type: none"> <li>• Profit margin can be expected to increase due to increased resource recovery and minimised raw material losses, reduced consumption of water and water treatment chemicals, reduced wastewater treatment cost, disposal cost for solid wastes and sludges</li> <li>• Market potential may be enhanced due to improved product quality</li> </ul>
<ul style="list-style-type: none"> <li>• Space limitation for installing CP measures and/or wastewater treatment plants</li> <li>• High cost of land and factory space for treatment equipment</li> <li>• High treatment equipment cost and recurrent operating cost of treatment</li> </ul>	<ul style="list-style-type: none"> <li>• In general, improved cleaning and maintenance procedures do not require separate dedicated space</li> <li>• In-plant measures require limited space, e.g. control of water and chemical usage, and recycling of process water</li> <li>• Highly mechanised treatment system require less space, but involve higher investment cost</li> <li>• The investment cost can be justified by the cost-savings due to reduced production costs.</li> </ul>

Table 9: Addressing Factory Constraints (cont.)

Factory Constraints	Counter Arguments
Poor pay-back period	<ul style="list-style-type: none"> <li>• Prices of water and electricity can be expected to increase in the future and thereby the pay-back time will become more attractive - normally can be brought down to below 2 years.</li> </ul>
Difficulty to access financing	<ul style="list-style-type: none"> <li>• Banks responding to the government's promptings are providing end-financing of up to 90%. Many incentive schemes are available to SMIs.</li> </ul>
Lack of access to technology	<ul style="list-style-type: none"> <li>• Some CP measures do not require specific waste management skills, but only technical skills to do proper maintenance and modifications of process lines.</li> </ul>
Inadequate waste management skills	<ul style="list-style-type: none"> <li>• Available from SIRIM, CETEC and CP consultants</li> <li>• Some CP measures do not require specific waste management skills, but only technical skills to do proper maintenance and modifications of process lines.</li> </ul>

## **8.0 INSPECTION FOCUS**

### **8.1 INTRODUCTION**

This is a particularly important Section of the Handbook as it attempts to guide the DOE Officers into performing the inspections as effectively and efficiently as possible.

A Manual on Practical Enforcement dealing with the general procedures for pre-inspection preparation, comprehensive inspection, and follow-up of inspection visits has been developed separately to assist DOE inspection officers in the conduct of their enforcement activities.

This Section on Inspection Focus is industry-specific for textile mills and serves as a supplement to the Practical Enforcement Manual.

The main purpose of this Section on Inspection Focus is to provide guidance on:

- Essential background information that must be obtained before the inspection;
- Preparation of inspection checklists that enlist essential inspection issues;
- Preparation of recording worksheets to be used during the inspection; and
- Preparation for the closing meeting with the factory management.

### **8.2 KEY ENVIRONMENTAL ISSUES**

The environmental issues of the textile industry are relatively less consequential than those of certain other industries, such as that the metal finishing industry or chemical industries that deal with some highly toxic and hazardous substances. The main environmental issues of the textile industry have been presented in *Section 4*. In summary, the key issues relate to:

- Type of chemical used, especially the dyes and pigments;
- Generation of a highly polluting effluent due to high organic content, presence of dye and pigment residues, and in some cases heavy metals;
- Poor interim storage of chemicals and inadequate housekeeping in some textile mills;
- Excessive occupational noise exposure; and
- Presence of airborne dust and solvent fumes in certain areas.

### 8.3 INSPECTION OBJECTIVES

The main objectives of the multi-media environment-based industrial inspection are:

- To monitor and ensure compliance with the regulatory requirements of environmental legislation;
- To observe the conditions of housekeeping and assess the potential for cleaner production;
- To identify the potential areas for improved waste management and pollution control;
- To identify obvious areas for improved waste treatment and waste utilisation;
- To investigate sources of public of complaints;
- To draw the attention of the management to potential areas for environmental performance improvement and cleaner production possibilities; and
- To demonstrate the DOE's commitment to enhance and protect the environment, and ensure fulfillment of the objectives and requirements of the EQA.

### 8.4 INSPECTION PROCEDURE AND STEPS

The principal steps involved in a textile mill inspection are:

- Pre-inspection planning and review of available factory background information;
- Factory inspection;
- Closing meeting with the factory management; and
- Reporting and follow-up action.

#### 8.4.1 Pre-inspection Planning and Information Review

(a) Mill Identification, Location and Existing Environmental Status

The DOE Enforcement Officer will need to familiarise himself with sufficient background information on the textile mill to be visited, and this should include:

- Mill identification, location, and landuse of immediate surroundings with the aid of a map;

- Manufacturing capacity and operating hours;
- Steam-generating capacities of boilers;
- Status of effluent discharge for at least two preceding quarters;
- Findings of previous inspection visits and any recommendations made.

(b) Textile Mill Manufacturing Processes and Sources of Pollution

It is important that the DOE officer is familiar with the following aspects of the textile mill to be visited prior to the inspection:

- Process flow chart;
- Manufacturing processes; and
- Waste generation;

This is most essential, as it gives all the inputs and outputs, including the effluent discharges. This and the other information referred to above will help the inspector to assess the mass balance himself, if the factory has not already worked-out one for him.

(c) Waste Management Systems

- Drawings of the waste management systems and effluent drainage systems of the factory:

This is essential to make sure that the factory has separate drainage systems for effluent and stormwater management. If the factory has not got a separate drainage system for stormwater, it is likely that this stormwater will join the effluent discharge and reduce the hydraulic retention time (HRT) of the treatment system;

- Water-supply and effluent discharge:
  - Source of water-supply including type of flow metering;
  - Data on raw and treated wastewater;
  - Type of waste-receiving watercourse and their downstream beneficial uses;
- Engineering drawings and plans of the effluent treatment and other waste management systems:

These would be useful to verify the principal design features of the systems and any observed deficiencies needing rectification;

- Air emissions:

Information is needed on whether the textile mill operates any control systems to reduce smoke emission from its boilers and incinerators and analytical data to establish the efficiency of such systems should be obtained.

Much of the needed information may be available in the industry source files maintained by the DOE. If the relevant information is not available in the files, then it should be obtained through the usual mechanisms employed by the DOE.

## 8.4.2 Factory Inspection

While the textile mill inspection primarily aims at compliance-monitoring, waste auditing of the facility should also be performed. Thus, the textile mill inspection should involve the following:

- Opening meeting
- Document review
- Inspection of the factory premises
- Use of inspection checklists and inspection worksheets
- Effluent sampling and analysis

(a) Opening Meeting

An opening meeting is an important element of the inspection visit. The meeting should be held with the factory management to explain the purpose of the visit and how the inspection will be carried out. In some cases, it may address specific concerns that the Inspector may have (e.g. as a result of a complaint the DOE may have received), regarding certain adverse environmental impacts of the mill's operations.

(b) Document Review

It is preferable to conduct the review of the relevant documents before the site inspection. In general, the Inspector should review the available documents to gain a better understanding of the key issues involved.

The documents should include:

- Previous inspection reports of the DOE officers;
- Records of production data, water consumption, effluent discharge data, etc. previously obtained;
- Relevant analytical data, i.e. the effluent analysis and air emission analysis;
- Records of complaints, if any, and how the mill management resolved the issues involved;
- Treatment process flow diagrams and treatment plant plans

(c) Interviews

The interview phase of the inspection visit can be an important aspect of the process as the Inspector can obtain details not found in records, as well as to familiarise with the mill operation. The success of the interviews will depend on the inter-personal skill of the Inspector as well as his technical knowledge.

The interview should be such as to convey the message to the facility management and operators that the Inspector has not come as a prosecutor or a judge, but to jointly review the whole operation from an environmental perspective, and to provide guidance to the management on how to improve the operation to achieve greater success in managing the environmental aspects and issues and facilitate compliance with the DOE regulatory requirements.

The findings of the interviews should be verified through record checks, site inspection and further interviews, if necessary. Such a step will help the Inspector avoid drawing conclusions of certain matters based on mere hearsay.

(d) Inspection of Factory Premises

This is the most important aspect of the factory inspection. There are many ways of conducting a site inspection. But the most commonly practised method is the general planned walk-through

inspection. The Inspector examines everything from the raw material reception area to the dispatch of finished products, using the process flow chart obtained earlier. The inspector should:

- evaluate housekeeping and in-plant process control.
- examine the process line, and where possible:
- inspect all areas, including obscure areas;
- observe operations during times of effluent discharge; and
- observe sampling and monitoring procedures.

The process line inspection is mainly to ensure that the effluent generation and discharge points are the same as those shown in the process flow diagram.

- inspect the treatment plant, and observe for the following:
- type of treatment system;
- adequacy of basic design;
- status of operation and maintenance;
- regularity of sludge removal and sludge return in activated sludge treatment systems (if any);
- status of compliance with effluent discharge standards;
- any special features of improved design or operation.

The Inspector should review the pre-treatment and treatment plant operations by visiting the treatment plants.

(c) Use of Inspection Checklists and Worksheets

To carry-out the inspection of the factory premises effectively, the use of checklists are essential for providing guidance, and worksheets to systematically record the observations and findings. For this purpose, two checklists and two worksheets have been developed.

These are:

- Checklist on status of good housekeeping and cleaner production;

- Checklist on status of regulatory compliance;
- Recording worksheet on status of good housekeeping and cleaner production; and
- Recording worksheet on status of regulatory compliance.

(i) Inspection Checklist on Status of Good Housekeeping and Cleaner Production:

An inspection checklist for good housekeeping is highly necessary to provide guidance and a reminder on what to look for in this area. A comprehensive list is provided in the attached **Appendix 1**. It highlights the production flow sequence and inspection items for each station, including the cleaner production opportunities.

(ii) Recording Worksheet on Status of Good Housekeeping and Cleaner Production:

The detailed worksheet is provided in **Appendix 2**. It covers the inspection area, observations, evidences taken and findings based on three(3) qualifiers – satisfactory, unsatisfactory and further investigation.

(iii) Checklist on Status of Regulatory Compliance:

This checklist is attached as **Appendix 3** and it contains the final discharge status, regulatory requirements and inspection focus.

(iv) Recording Worksheet on Status of Regulatory Compliance:

This recording worksheet is attached as **Appendix 4** and is for documenting information and data on the status of the final effluent discharge, inspection focus, evidences and findings.

(f) Sampling and Analysis of Textile Mill Effluents

The main characteristics of textile mill effluents are determined by the following parameters:

- pH
- Total Solids (TS)
- Suspended Solids (SS)
- Chemical Oxygen Demand (COD)

- Biochemical Oxygen Demand (BOD; 5-Day, 20°C)
- Heavy Metals
- Total Nitrogen (TN)
- Ammoniacal Nitrogen (AN)
- Phosphates (P)
- Detergents
- Oil & Grease (O&G)
- Temperature (°C)

(i) Sampling of Textile Mill Effluents:

The basic objectives of representative effluent sampling are:

- To obtain a sample whose concentrations of determinants are representative of those in the effluent at the time of sampling; and
- To ensure that the concentrations of the determinants in the samples do not change between sampling and laboratory-based analysis.

If these objectives are not achieved, the analytical results may be partially or completely invalid for their intended purposes.

(ii) Sampling Apparatus:

The type of sampling equipment and apparatus required to obtain representative effluent samples depend on the sampling technique to be employed. Representative sampling techniques include:

- Flow-proportional sampling and compositing of effluent; and
- Time-composite sampling.

Sampling may be performed manually, semi-manually or with the use of automatic sampling equipment consisting of flow monitors and flow proportional samplers. Time-composite samples may be taken manually or with the use of automatic samplers. The apparatus used for sampling may therefore range from simple hand-operated vessels, such as beakers and buckets, to

sophisticated automatic devices which take constant volume samples at specified time intervals or, which take sample volumes proportional to the effluent flow rate.

Sample containers should be of material that will not contaminate the sample. Chemical-resistant glass and polyethylene are suitable materials for containers.

Coloured bottles are preferred for BOD test samples as they limit light penetration and consequently inhibit microbial activity which can otherwise change the effluent characteristics prior to testing.

All sample containers should be provided with stoppers, caps or plugs of suitable material that can resist the attack by the vessel's contents. Containers should be carefully cleaned before use to remove all extraneous surface dirt. Before filling, the sample container should be rinsed out two or three times with the effluent to be sampled.

(iii) Sampling Techniques:

The chemical analysis is generally intended to reveal the composition of the effluent at the time of sampling. As the composition of effluent varies with time, it is recommended that a time-composite sample be taken for chemical analysis in order to represent an average condition of the total effluent discharged for the day of production.

In order to get a time-composite sample, a minimum of six individual samples should be collected at regular time intervals over a minimum period of one 8-hour shift during the operation of the factory. The individual samples taken should be refrigerated immediately to 4°C and kept at this temperature during the compositing period. At the end of the compositing period, the composite sample should be mixed thoroughly and a suitably-sized portion taken for performance of the chemical analysis. Usually 1-litre portion of the composite sample is sufficient for a complete effluent analysis.

The sampling point for the factory effluent should be carefully chosen to ensure that the total combined factory effluent that is finally discharged from the factory premises is being sampled. This is the point at which the effluent emerges from the premises or treatment plant or the point prior to the discharge of effluent into a watercourse or any soil or surface of land. The sampling point must be acceptable to the DOE. Reference should be made to the plans for approving the construction of the mill and treatment plant.

A record should be made of every sample collected and each sample should be clearly labeled. The record should contain sufficient information to provide positive identification of the sample as well as the name of the sample collector, the date, time and exact sample location, the weather

condition and any other data which may help in the interpretation of the analytical results.

(iv) *Sample Preservation:*

Because of likely changes that take place on standing, it is desirable that analyses be made as soon as possible after collection of samples. However, this is not always feasible as the textile mills may be located far from laboratories. In order to prevent, or at least to minimise the changes in their properties, the effluent samples should be preserved according to the techniques given in **Table 10**.

**Table 10: Parameter-Based Preservation Techniques for Effluent Samples**

Parameter	Preservation Technique	Maximum Holding Period
Acidity	Refrigeration at 4°C	24 hours
Alkalinity	Refrigeration at 4°C	24 hours
BOD	Refrigeration at 4°C	6 hours
COD	Add 2 ml H <sub>2</sub> SO <sub>4</sub> /litre sample	7 days
Solids	None available	7 days
Total Kjeldahl Nitrogen	Add 40 mg HgCl <sub>2</sub> /litre sample at 4°C	Unstable
Ammoniacal nitrogen	Add 40 mg HgCl <sub>2</sub> /litre sample at 4°C	7 days
Nitrate	Add 40 mg HgCl <sub>2</sub> /litre sample at 4°C	7 days
Nitrite	Add 40 mg HgCl <sub>2</sub> /litre sample at 4°C	7 days
Sulphate	Refrigeration at 4°C	7 days
Sulphide	Add 2 ml Zinc acetate 1 N/litre sample	7 days
Phosphate	Add 40 mg HgCl <sub>2</sub> /litre sample at 4°C	7 days
Metals	Add 5 ml HNO <sub>3</sub> /litre sample	6 months

### 8.4.3 Closing Meeting

The closing meeting should be held with the factory management following the inspection of the factory premises and the treatment plant, and after the Inspector has had time to note the main points for presentation and discussion.

The closing meeting should aim at accomplishing the following:

- Sum up the observations and findings;
- Ensure a common understanding on the findings to avoid any misunderstanding;
- Enhance the environmental awareness of the factory personnel;
- Explain and issue compounds, if necessary;
- Inform the management of any needed follow-up action in response to areas of non-compliance;
- Arrange for a follow-up visit, if necessary;
- Discuss possible improvements of the factory's good housekeeping, treatment system, etc.;
- Clarify and confirm any agreement recorded; and
- Discuss any other matters of mutual interest or concern.

#### 8.4.4 Reporting and Follow-up Action

The main purposes of reporting and follow-up action are to ensure that:

- All information and data collected are well-documented, registered, filed and used appropriately;
- Suggestions on further actions are taken to enhance compliance;
- The facility operator and the management are aware of the requirements for any needed improvement of their environmental performance; and
- DOE's general commitment to enforcement of the EQA is well demonstrated.

Further information on reporting and follow-up action can be found in the *Practical Enforcement Manual*.

# ANNEX A

## PRINTING TECHNIQUES USED IN THE TEXTILE INDUSTRY

- ***Rotary Screen Printing***

Rotary screen printing uses seamless cylindrical screens made of metal foil. The machine uses a rotary screen for each color. As the fabric is fed under uniform tension into the printer section of the machine, its back is usually coated with an adhesive, which causes it to adhere to a conveyor printing blanket. Some machines use other methods for gripping the fabric. The fabric passes under the rotating screen through which the printing paste is automatically pumped from pressure tanks. A squeegee in each rotary screen forces the paste through the screen onto the fabric as it moves along. The fabric then passes to a drying-oven.

- ***Direct Printing***

In direct printing, a large cylindrical roller picks up the fabric, and smaller rollers containing the color are brought into contact with the cloth. The smaller rollers are etched with the design, and the number of rollers reflects the number of colors. Each smaller roller is supplied with color by a furnisher roller, which rotates in the color trough, picks up color, and deposits it on the applicator roller. Doctor blades scrape excess color off the applicator roller so that only the engraved portions carry the color to the cloth. The cloth is backed with a rubberized blanket during printing, which provides a solid surface to print against, and a layer of gray cloth between the cloth and the rubber blanket will absorb excess ink.

- ***Discharge Printing***

Discharge printing is performed on piece-dyed fabrics. The patterns are created through removal, rather than addition, of color, hence most discharge printing is done on dark backgrounds. The dyed fabric is printed using discharge pastes, which remove background color from the substrate when exposed to steam. Colors may be added to the discharge paste to create different colored discharge areas.

- ***Resist Printing***

Resist printing encompasses several hand and low-volume methods in which the pattern is applied by preventing color from penetrating certain areas during piece-dyeing. Examples of resist printing methods include batik, tie-dyeing, screen printing, and stencil printing.

- ***Ink-Jet Printing***

Ink-jet printing is a non-contact printing method in which droplets of colorant solution are propelled toward a substrate and directed to a desired spot. Ink jet is an emerging technology in the textile industry and has not yet been adopted for widespread commercial use. The dye types most amenable to ink-jet printing of textiles are fiber reactive, vat, sulfur, and naphthol dyes.

- ***Heat-transfer Printing***

In heat-transfer printing, the pattern is first printed onto a special paper substrate. The paper is then positioned against the fabric and subjected to heat and pressure. The dyes are transferred to the fabric via sublimation.

# ANNEX B

## MECHANICAL AND CHEMICAL FINISHING TECHNIQUES USED IN THE TEXTILE INDUSTRY

### Mechanical Treatment Techniques

- ***Heat-setting***

Heat-setting is a dry process used to stabilize and impart textural properties to synthetic fabrics and fabrics containing high concentrations of synthetics. When manmade fibers are heat-set, the cloth maintains its shape and size in subsequent finishing operations and is stabilized in the form in which it is held during heat-setting (e.g., smooth, creased, uneven). Textural properties may include interesting and durable surface effects such as pleating, creasing, puckering, and embossing. Heat-setting can also give cloth resistance to wrinkling during wear and ease-of-care properties attributed to improvements in resiliency and in elasticity. Pollution outputs may include volatile components of spin finishes if heat-setting is performed before scouring and bleaching processes. These components are introduced to the fabrics during the manufacture of synthetic fibers, when proprietary spin finishes are applied to provide lubrication and impart special properties, such as anti-static, to the fibre.

- ***Brushing and Napping***

Brushing and napping decrease the luster of fabrics by roughening or raising the fiber surface and change the feel or texture of the fabric. These processes involve the use of wires or brushes that pull individual fibres.

- ***Softening***

Calendering, or ironing, can be used to reduce surface friction between individual fibers, thereby softening the fabric structure and increasing its sheen. In calendering, the fabric passes through two or more rolls. Typically, one roll is made of chilled steel, while the other is made of a softer material like cotton fibers. The steel roll may also be heated using gas or steam. Once goods pass through the machine they are wound up at the back of the machine.

- ***Optical Finishing***

Luster can be added to yarns by flattening or smoothing the surfaces under pressure. This can be achieved by beating the fabric surface or passing the fabric between calendering rolls. The lustre can be further increased if the rolls are scribed with closely spaced lines.

- ***Shearing***

Shearing is a process that removes surface fibers by passing the fabric over a cutting blade.

- ***Compacting***

Compacting, which includes the Sanforizing process, compresses the fabric structure to reduce stresses in the fabric. The Sanforizing process reduces residual shrinkage of fabrics after repeated laundering. The fabric and backing blanket are fed between a roller and a curved braking shoe, with the blanket under tension. The tension on the blanket is released after the fabric and blanket pass the braking shoe. Compacting reduces the potential for excessive shrinkage during laundering.

## **Chemical Treatment Techniques**

- ***Optical Finishes***

Optical finishes added to either brighten or deluster the textile.

- ***Absorbent and Soil Release Finishes***

These finishes that alter surface tension and other properties to increase water absorbency or improve soil release.

- ***Softeners and Abrasion-resistant Finishes***

Softeners and abrasion-resistant finishes are added to improve feel or to increase the ability of the textile to resist abrasion and tearing.

- ***Physical Stabilization and Crease-resistant Finishes***

These finishes, which may include formaldehyde-based resin finishes, stabilize cellulosic fibers to laundering and shrinkage, imparting permanent press properties to fabrics.

# ANNEX C

## PARAMETER LIMITS OF EFFLUENT OF STANDARDS A AND B APPLICABLE TO THE TEXTILE INDUSTRY

PARAMETER	UNIT	STANDARDS	
		A*	B
Temperature	°C	40	40
pH value	-	6.0-9.0	5.5-9.0
BOD <sub>5</sub> at 20°C	mg/l	20	50
COD	mg/l	50	100
Suspended solids	mg/l	50	100
Mercury	mg/l	0.005	0.05
Cadmium	mg/l	0.01	0.02
Chromium, Hexavalent	mg/l	0.05	0.05
Arsenic	mg/l	0.05	0.10
Cyanide	mg/l	0.05	0.10
Lead	mg/l	0.10	0.5
Chromium, Trivalent	mg/l	0.20	1.0
Copper	mg/l	0.20	1.0
Manganese	mg/l	0.20	1.0
Nickel	mg/l	0.20	1.0
Tin	mg/l	0.20	1.0
Zinc	mg/l	1.0	1.0
Boron	mg/l	1.0	4.0
Iron (Fe)	mg/l	1.0	5.0
Phenol	mg/l	0.001	1.0
Free Chlorine	mg/l	1.0	2.0
Sulphide	mg/l	0.5	0.50
Oil and Grease	mg/l	not detectable	10.0

\* This effluent standard applies to the discharge of sewage or industrial effluent within a water-supply catchment area upstream of a public water-supply intake

Source: Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979

# ANNEX D

## AIR EMISSION STANDARDS APPLICABLE TO THE TEXTILE INDUSTRY

SUBSTANCE EMITTED	SOURCES OF EMISSION	STANDARDS
Dust and other particulates	Any source	0.4 gm/ Nm <sup>3</sup>
<b>Metal and metallic compounds</b>		
• Mercury	Textile industry	0.010 gm/Nm <sup>3</sup>
• Cadmium	Textile industry	0.015 gm/Nm <sup>3</sup>
• Lead	Textile industry	0.025 gm/Nm <sup>3</sup>
• Antimony	Textile industry	0.025 gm/Nm <sup>3</sup>
• Arsenic	Textile industry	0.025 gm/Nm <sup>3</sup>
• Zinc	Textile industry	0.100 gm/Nm <sup>3</sup>
• Copper	Textile industry	0.100 gm/Nm <sup>3</sup>
<b>Gaseous Substances</b>		
(a) Acid gases	Manufacture of H <sub>2</sub> SO <sub>4</sub>	3.5 gm of SO <sub>3</sub> eq/Nm <sup>3</sup> and free of persistent mist
(b) Sulphuric acid mist or SO <sub>3</sub> or both	Any source other than (a)	0.2 gm of SO <sub>3</sub> eq/Nm <sup>3</sup> and free of persistent mist
(c) Chlorine gas	Any source	0.2 gm of HCl/Nm <sup>3</sup>
(d) Hydrogen chloride	Any source	0.4 gm of HCl/Nm <sup>3</sup>
(e) Fluorine, hydrofluoric acid, inorganic fluorine compounds	Aluminium manufacturing from alumina	0.20 gm of HF acid/ Nm <sup>3</sup>
(f) Fluorine, hydrofluoric acid, inorganic fluorine compounds	Any source other than (e) above	0.10 gm of HF acid/ Nm <sup>3</sup>
(g) Hydrogen sulphide	Any source	5 ppm (volume/volume)
(h) Oxides of nitrogen	Nitric acid manufacturing	1.7 gm SO <sub>3</sub> eq/Nm <sup>3</sup> and substantially colourless
(i) Oxides of nitrogen	Any source other than (h) above	2.0 gm SO <sub>3</sub> eq/Nm <sup>3</sup>

Source: Environmental Quality (Clean Air) Regulations, 1978

# ANNEX E

## SCHEDULED WASTE REGULATORY PROVISIONS APPLICABLE TO THE TEXTILE INDUSTRY

REGULATORY PROVISION	REGULATION NUMBER/ ORDER
<ul style="list-style-type: none"> <li>• 107 categories of wastes have been classified as scheduled wastes</li> <li>• Wastes generator to ascertain whether waste generated is classified as scheduled waste</li> <li>• New generators of scheduled waste are required to notify the DOE within one month from the date of generation of waste</li> </ul>	<ul style="list-style-type: none"> <li>• Environmental Quality (Scheduled Wastes) Regulations, 1989 : Section 2, First Schedule</li> <li>• Environmental Quality (Scheduled Wastes) Regulations, 1989: Section 2, First Schedule</li> <li>• Environmental Quality (Scheduled Wastes) Regulations, 1989: Section 3, Second Schedule</li> </ul>
<ul style="list-style-type: none"> <li>• Scheduled wastes can be stored, recovered and treated within the premises of the waste generator. Such activities do not require licensing by the DOE</li> <li>• However, land farming, incineration, ultimate disposal and off-site facilities for recovery, storage and treatment can only be carried out at prescribed premises licensed by the DOE</li> </ul>	<ul style="list-style-type: none"> <li>• Environmental Quality (Scheduled Wastes) Regulations, 1989: Section 5</li> <li>• Environmental Quality (Scheduled Wastes Treatment and Disposal Facilities) Order, 1989: Section 3</li> </ul>
<ul style="list-style-type: none"> <li>• Waste generators shall also keep an up-to-date inventory of scheduled wastes generated, treated and disposed off</li> <li>• Proper labeling of, containers and storage areas as well as avoidance of storage of incompatible wastes are also to be ensured</li> </ul>	<ul style="list-style-type: none"> <li>• Environmental Quality (Scheduled Wastes) Regulations, 1989: Section 9, Fifth Schedule</li> <li>• Environmental Quality (Scheduled Wastes) Regulations, 1989: Section 8(2) and 8(3), Third Schedule</li> </ul>

REGULATORY PROVISION	REGULATION NUMBER/ ORDER
<ul style="list-style-type: none"> <li>• In the case of transportation of waste from the premises of the waste generator to the treatment and disposal facilities, such transportation shall conform to the consignment note system whereby the movement of waste is monitored until it reaches the approved destination</li> <li>• It is the responsibility of a waste generator to monitor and ensure that the waste transported from this factory reaches the approved destination</li> <li>• The waste generator is responsible for informing the transport contractor regarding the nature of the waste and what actions are to be taken during any accident to minimise damage to human life and the environment</li> </ul>	<ul style="list-style-type: none"> <li>• Environmental Quality (Scheduled Wastes) Regulations, 1989: Section 10, Sixth Schedule</li> <li>• Environmental Quality (Scheduled Wastes) Regulations, 1989: Section 7</li> <li>• Environmental Quality (Scheduled Wastes) Regulations, 1989: Section 11</li> </ul>

*Source : Environmental Quality (Scheduled Wastes) Regulations, 1989 and Environmental Quality (Scheduled Wastes Treatment and Disposal Facilities) Order, 1989*

# ANNEX F

## GUIDELINES ON ACCEPTABLE NOISE LEVELS AT FACTORY PERIMETER FENCE

The noise at the factory boundary fence should exceed the following levels :

REGULATORY PROVISION	REGULATION NUMBER/ ORDER
60 dBA during daytime	7 am - 10 pm
50 dBA during night-time	10 pm - 7 am

*Source : DOE Guidelines on the Siting and Zoning of Industries, 1976 (revised 1994)*

# ANNEX G

## G.1 Hing Yap Knitting Industries Berhad, Taman Kepong, Kuala Lumpur

- **Manufactured Products**

- Knitted fabrics and knitted garments

- **Manufacturing Processes**

- Weft knitting for production of fabric
- Winch (beck) dyeing for coloration and treatment of cloth; the reactive dye is used which is biodegradable, water soluble and non-toxic. Water usage is 1:10 (every kg of fabric uses 10 kg of water)
- Design and sampling based on the creative input of fashion
- Tailoring and cutting of the garment components
- Sewing and assembly of clothing parts

- **Combined Raw Wastewater Characteristics**

pH	:	10
BOD	:	500 mg/L
COD	:	1,000 - 1,200 mg/L

- **Wastewater Treatment System**

*Figure G.1* is a process flow diagram representing the wastewater treatment system for the combined wastewater from the knitting textile mill at Hing Yiap Knitting Industries Bhd. The treatment system consists of the following principal treatment units:

- Raw effluent collection pit
- Cooling tower
- pH adjustment
- Activated sludge system with diffused air aeration and nutrient addition; the clarification is polymer-aided
- Physico-chemical treatment of the effluent from the activated sludge system involving pH adjustment, coagulation, flocculation, chemical removal and clarification in a lamella separator
- Filter press for sludge dewatering

## G.2 Ramatex Textiles Industrial Sdn. Bhd., Batu Pahat, Johore

- **Manufactured Products**

- Cotton yarn, knitted fabrics and garments

- **Manufacturing Processes**

- Yarn formation from cotton (natural fibre)
- Knitting (weft) for the production of fabric, both cotton and blended, which includes economy value cotton (65%) + 35% polyester tetron cotton (65% polyester + 35% cotton)
- Dyeing and Finishing: (Air-Flow Aerodynamic System) computer-aided jet-dyeing machines with extremely low water usage of 1:3 (1 kg of fabric requires only 3 kg of water) are used compared to a water usage of 1:20 for winch (Beck) dyeing and 1:12 for rapid dyeing (Jet dyeing); the machinery investment pay-back period is 3 years due to savings in chemical and water usage and wastewater treatment cost. Non-toxic, water-soluble and biodegradable reactive dyes of the sulfonate group are used. High reduction of salt and chemicals as well as resulting wastewater volume and pollutant load.

- **Combined Raw Wastewater Characteristics**

Combined Wastewater	:	5,040 m <sup>3</sup> /d
pH	:	9.3 - 9.8
BOD	:	150 - 200 mg/L
COD	:	450 - 500 mg/L
Oil & Grease	:	40 - 50 mg/L

- **Wastewater Treatment System** (being implemented)

*Figure G.2* is a process flow diagram representing the wastewater treatment system for the combined wastewater from the textile mill at Ramatex Textile Industrial Sdn. Bhd. The treatment system consists of the following principal treatment units:

- Balancing tank
- Coagulation and flocculation
- Primary clarification
- Sequencing batch reactor (SBR)
- Gravity sludge thickener and sludge drying bed

### G.3 Hualon Corporation (M) Sdn. Bhd., Melaka

- **Manufactured Products**

- 100 tonnes per day of polyester, nylon and polyester-cotton finished fabrics

- **Manufacturing Processes**

- Knitting (Weft)
- Weaving (Water-jet Looms)
- Dyeing and Finishing: Rapid (jet) dyeing with water ratio 1:7 at high temperature (120 - 130 °C) and high pressure; non-toxic, water-soluble acid dye for nylon and non-toxic, non-water soluble disperse dye for polyester are used.

- **Combined Raw Wastewater Characteristics**

Weaving Plant Wastewater	:	5,500 m <sup>3</sup> /d (about 60% recycled)
Dyeing Plant Wastewater	:	5,000 m <sup>3</sup> /d
pH	:	7
COD	:	300 - 12,000 mg/L

- **Wastewater Treatment System**

*Figure G.3* is a process flow diagram representing the wastewater treatment system for the individual and combined wastewater streams from the Hualon Corporation (M) Sdn. Bhd. textile mill in Melaka, which is required to meet Standard B of the Sewage and Industrial Effluents Regulations. The treatment system consists of the following principal treatment units:

- Equalisation
- pH adjustment
- Primary sedimentation
- Cooling
- Coagulation and flocculation
- Dissolved air flotation
- Contact bioreactor
- Chemical treatment, flocculation and chemical sedimentation
- Sludge dewatering Dehydrator Filter Press

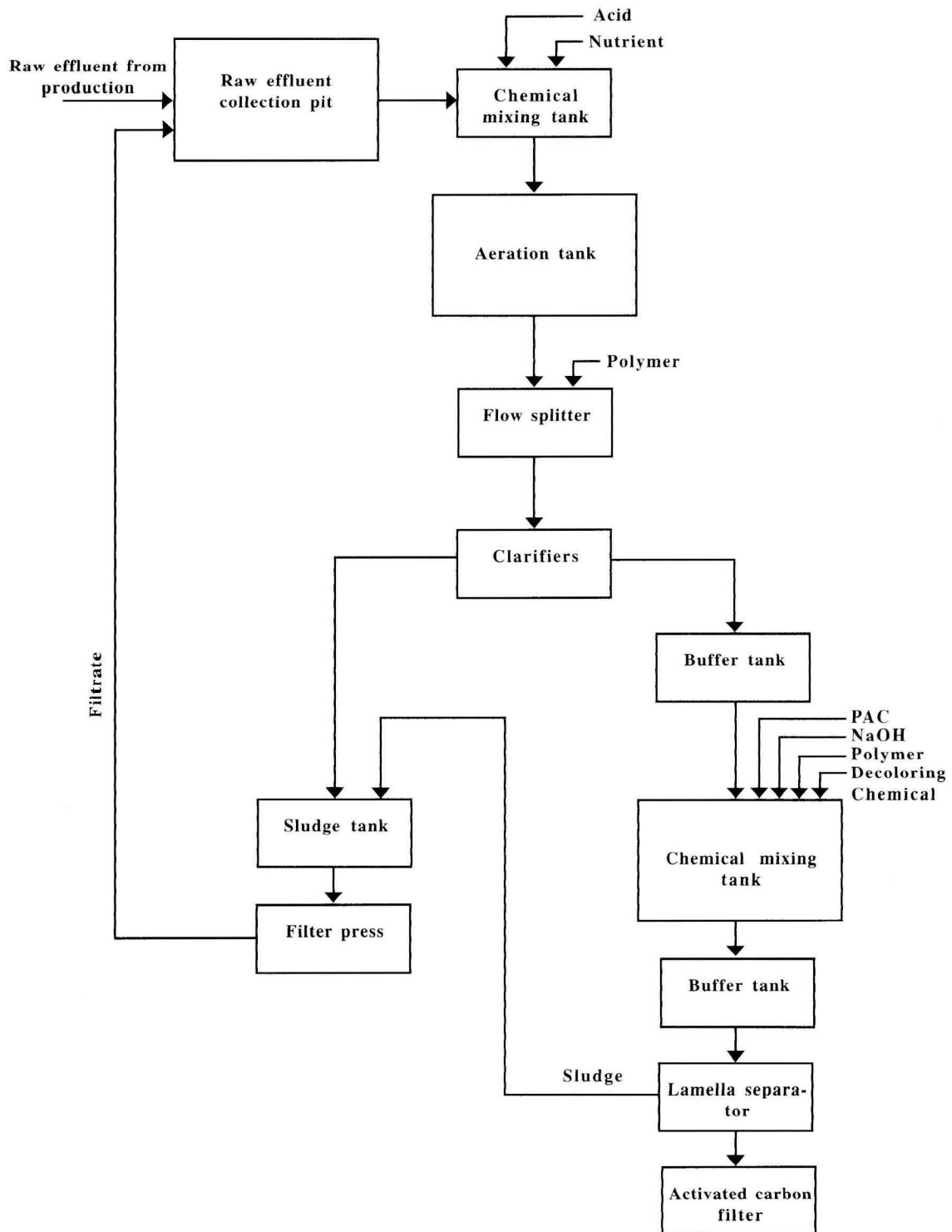


Figure G1: Wastewater Treatment System for Knitting Mill Wastewater at Hing Yiap Knitting Industries Bhd., Taman Kepong, Kuala Lumpur

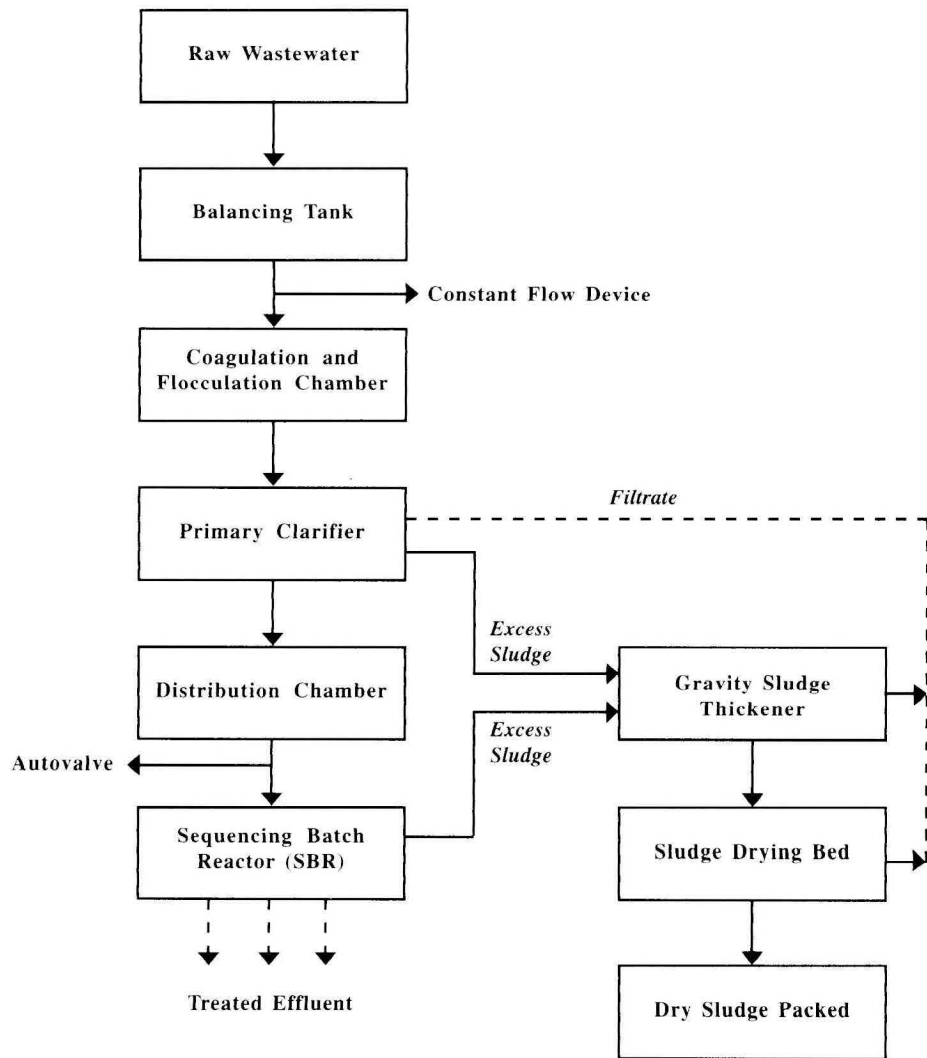


Figure G2: Wastewater Treatment System for Combined Wastewater from Manufacture of Cotton Yarn, Knitted Fabrics and Wet Processing at Ramatex Textiles Industrial Sdn. Bhd. Sri Gading Industrial Estate, Batu Pahat, Johore.

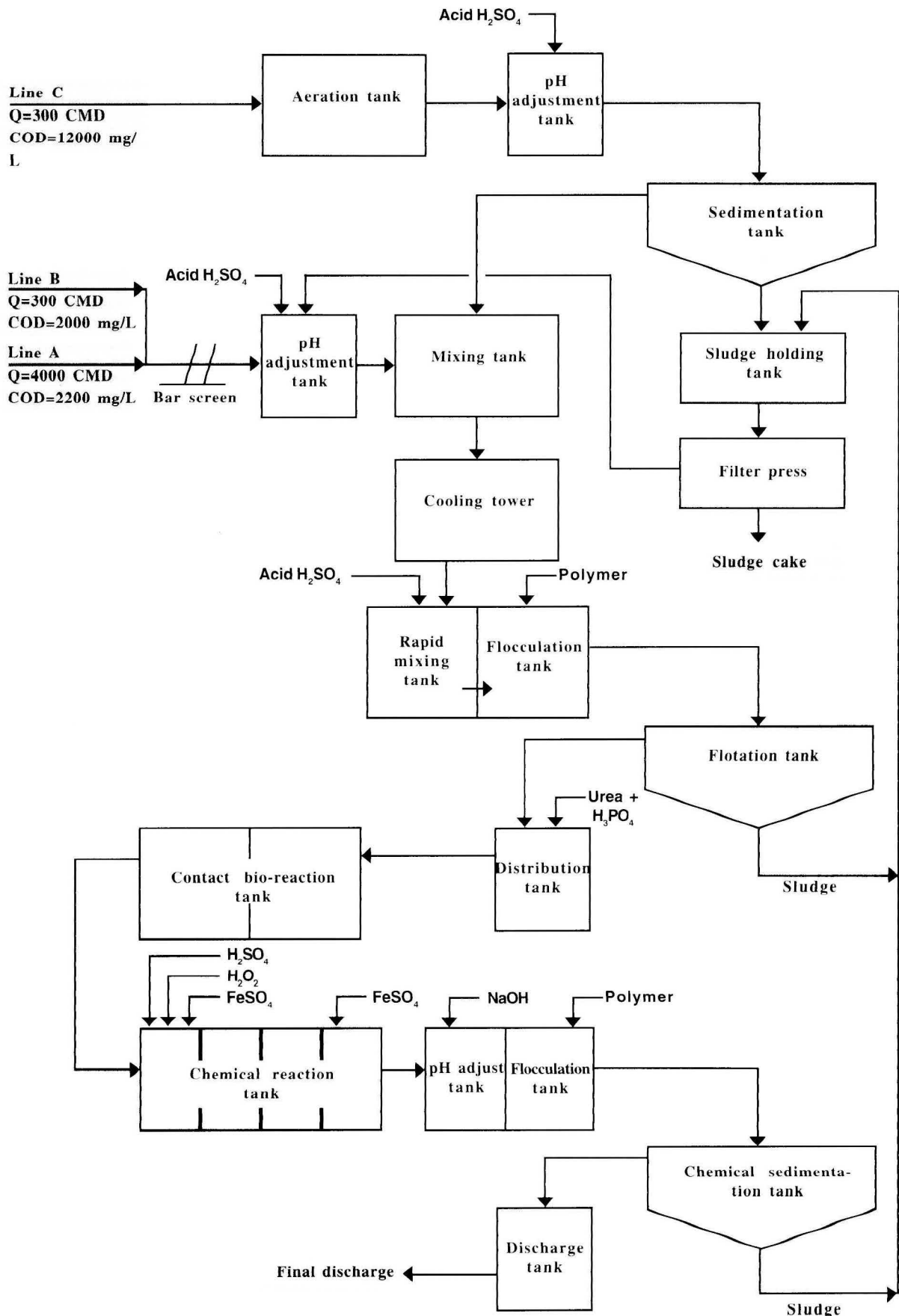


Figure G3: Wastewater Treatment System for Individual/Combined Wastewater from manufacture and wet processing of Synthetic and Mixed Knitted and Weaved Fabrics at the Melaka Textile Mill of Hualon Corporation (M) Sdn. Bhd.

# APPENDIX 1

## Inspection Checklist for Good Housekeeping and Cleaner Production

No. Production Flow Sequence	Model Situation	Inspection Focus
1. Raw materials reception area	Production areas clean, tidy and free of spillages, packaging wastes, empty containers, debris, etc.	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Chemical spillages on floors</li> <li>- Empty containers and packaging wastes in production areas</li> <li>- Uncollected debris from broken pallets, wooden containers, etc.</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- Recovery of recyclable and/or utilisable waste materials</li> </ul>
2. Fibre preparation	<ul style="list-style-type: none"> <li>- Clean and tidy production area</li> <li>- Free of fibre waste, packaging wastes and hard waste</li> <li>- Relatively free of air borne dust</li> </ul>	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Fibre waste, packaging wastes and hard waste lying in the production areas</li> <li>- Dusty atmosphere</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- Recovery of recyclable and/or utilisable waste materials</li> <li>- Removal of all dirt and hard waste materials</li> <li>- Good general ventilation and/or local air extraction systems for dust control to enhance occupational health of workers</li> </ul>
3. Yarn spinning	<ul style="list-style-type: none"> <li>- Clean and tidy production areas</li> <li>- Free of fibre waste, sized yarn, packaging wastes, cleaning and processing wastes</li> <li>- Relatively free of air borne dust</li> </ul>	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Fibre waste, sized yarn, packaging wastes, cleaning and processing wastes in production areas</li> <li>- Dusty atmosphere</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- Recovery of recyclable and/or utilisable waste materials</li> <li>- Good general ventilation and/or local air extraction systems for dust control to enhance occupational health of workers</li> </ul>
4. Slashing/sizing	<ul style="list-style-type: none"> <li>- Production areas clean, tidy and free of spillages, packaging waste, empty containers, debris, etc.</li> <li>- Relatively free of air borne VOCs</li> <li>- Minimised waste/wastewater generation and content (BOD; COD; metals; cleaning waste; size)</li> </ul>	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Chemical spillages on floors</li> <li>- Perceptible air borne VOCs</li> <li>- Undesirable waste/wastewater characteristics</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- Adequate waste/wastewater minimisation measures</li> </ul>

No. Production Flow Sequence	Model Situation	Inspection Focus
5. Weaving	<ul style="list-style-type: none"> <li>- Clean and tidy production area</li> <li>- Free of yarn and fabric scraps</li> <li>- Free of lubrication oil spillages</li> <li>- Acceptable noise levels and/or adequate hearing protection for workers</li> </ul>	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Yarn and fabric scraps on floors in production areas</li> <li>- Spillages of lubrication oils</li> <li>- Occupational noise concerns and availability of hearing protection</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- Recovery of utilisable off-spec fabric materials</li> <li>- Recycling of lubrication oils</li> <li>- Adequate hearing protection of workers</li> </ul>
6. Knitting	<ul style="list-style-type: none"> <li>- Clean and tidy production areas</li> <li>- Free of yarn and fabric scraps, and packaging wastes</li> <li>- Relatively free of airborne dust</li> <li>- Acceptable noise levels and/or adequate hearing protection for workers</li> </ul>	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Yarn and fabric scraps, packaging wastes on floors in production areas</li> <li>- Dusty atmosphere</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- Recovery of utilisable off-spec fabric materials</li> <li>- Good general ventilation and/or local air extraction systems for dust control to enhance occupational health of workers</li> <li>- Adequate hearing protection of workers</li> </ul>
7. Tufting	<ul style="list-style-type: none"> <li>- Production areas clean, tidy and free of packaging waste, yarn and fabric scraps</li> </ul>	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Yarn and fabric scraps, packaging wastes on floors in production areas</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- Recovery of utilisable off-spec fabric materials</li> </ul>
8. Desizing	<ul style="list-style-type: none"> <li>- Clean and tidy production areas</li> <li>- Free of fibre lint, yarn and fabric scraps,</li> <li>- Cleaning materials (wipes, rags, filters, etc.)</li> <li>- Containing solvents</li> <li>- Free of lubrication oil spillages</li> <li>- Minimised waste/wastewater generation (water-soluble sizes; synthetic sizes; lubricants; biocides; anti-static compounds)</li> <li>- Relatively free of airborne VOCs (glycol ethers)</li> <li>- Adequate respiratory protection for workers (if necessary)</li> </ul>	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Yarn and fabric scraps, fibre lint, cleaning materials in production areas</li> <li>- Spillages of lubrication oils and perceptible airborne VOCs</li> <li>- Undesirable waste/wastewater characteristics</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- Recovery of utilisable waste materials</li> <li>- Recycling of lubrication oils</li> <li>- Adequate respiratory protection of workers, if necessary</li> <li>- Adequate waste/wastewater minimisation measures</li> </ul>

No. Production Flow Sequence	Model Situation	Inspection Focus
9. Scouring	<ul style="list-style-type: none"> <li>- Clean and tidy production areas</li> <li>- Relatively free of airborne VOCs especially from glycol ethers and scouring solvents</li> <li>- Minimised waste/wastewater generation (disinfectants; insecticide residues; fats; oils; pectin; wax; knitting lubricants; spin finishes; spent solvents</li> <li>- Adequate respiratory protection for workers (if necessary)</li> </ul>	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Spillages of lubrication oils and perceptible airborne VOCs</li> <li>- Undesirable waste/wastewater characteristics</li> <li>- Adequacy of respiratory protection for workers</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- Recovery of recyclable and/or utilisable waste materials</li> <li>- Adequate dust control to enhance occupational health of workers</li> <li>- Adequate waste/wastewater minimisation measures</li> </ul>
10. Bleaching	<ul style="list-style-type: none"> <li>- Production areas clean, tidy and free of chemical spillages</li> <li>- Relatively free of chemical vapours</li> <li>- Minimised waste/wastewater generation (hydrogen peroxide; sodium silicate or organic stabiliser; pH)</li> </ul>	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Chemical wastage and spillages on floors of production areas</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- Chemical substitutions</li> </ul>
11. Singeing	<ul style="list-style-type: none"> <li>- Clean and tidy production areas</li> <li>- Relatively free of exhaust gases from burners</li> <li>- Respiratory protection for workers, if needed</li> </ul>	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Adequacy of general ventilation to minimise accumulation of exhaust gases from burners</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- Adequate general ventilation to minimise accumulation of exhaust gases from burners</li> </ul>
12. Mercerizing	<ul style="list-style-type: none"> <li>- Clean and tidy production areas</li> <li>- Minimised waste/wastewater</li> </ul>	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Undesirable waste/wastewater characteristics</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- Adequate waste/wastewater minimisation measures</li> </ul>
13. Heat-setting	<ul style="list-style-type: none"> <li>- Clean and tidy production areas</li> <li>- Relatively free of airborne VOCs from finish agents applied during synthetic fibre manufacture</li> </ul>	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Perceptible airborne VOCs</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- (Not significant )</li> </ul>

No.	Production Flow Sequence	Model Situation	Inspection Focus
14.	Dyeing	<ul style="list-style-type: none"> <li>- Production areas clean, tidy and free of chemical spillages</li> <li>- Relatively free of chemical vapours/VOCs</li> <li>- Minimised waste/wastewater generation (metals; salts; surfactants; toxics; organic processing assistants; cationic materials; color; BOD; COD; sulphide; acidity; spent solvents)</li> <li>- Adequate personal protective clothing and respiratory protection for workers, if needed</li> </ul>	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Chemical wastage and spillages on floors of production areas</li> <li>- Perceptable airborne chemical vapours and VOCs</li> <li>- Undesirable waste/wastewater characteristics</li> <li>- Toxic chemicals that can be substituted</li> <li>- Adequacy of general ventilation to minimise accumulation of airborne chemical vapours and VOCs</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- Substitution of undesirable toxic chemicals</li> <li>- Adequate waste/wastewater minimisation measures</li> <li>- Adequate general ventilation to minimise accumulation of airborne chemical vapours and VOCs</li> </ul>
15.	Printing	<ul style="list-style-type: none"> <li>- Clean and tidy production areas</li> <li>- Relatively free of exhaust gases from curing ovens and combustion processes</li> <li>- Minimised waste/wastewater generation (metals; suspended solids; urea; solvents; colour; heat; BOD; foam)</li> <li>- Adequate personal protective clothing and respiratory protection for workers, if needed</li> </ul>	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Chemical wastage and spillages on floors of production areas</li> <li>- Perceptable airborne chemical vapours and VOCs</li> <li>- Undesirable waste/wastewater characteristics</li> <li>- Toxic chemicals that can be substituted</li> <li>- Adequacy of general ventilation to minimise accumulation of exhaust gases from combustion processes</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- Substitution of undesirable toxic chemicals</li> <li>- Adequate waste/wastewater minimisation measures</li> <li>- Adequate general ventilation to minimise accumulation of exhaust gases from combustion processes</li> </ul>
16.	Finishing	<ul style="list-style-type: none"> <li>- Production areas clean, tidy and free of chemical spillages</li> <li>- Relatively free of chemical vapours/VOCs and especially formaldehyde vapours and combustion gases</li> <li>- Minimised waste/wastewater generation (BOD; COD; suspended solids; toxics; spent solvents)</li> <li>- Adequate personal protective clothing and respiratory protection for workers, if needed</li> </ul>	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Chemical wastage and spillages on floors of production areas</li> <li>- Perceptable airborne chemical vapours and VOCs</li> <li>- Undesirable waste/wastewater characteristics</li> <li>- Toxic chemicals that can be substituted</li> <li>- Fabric scraps, trimmings and packaging wastes</li> <li>- Adequacy of general ventilation to minimise accumulation of airborne chemical vapours and VOCs</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- Substitution of undesirable toxic chemicals</li> <li>- Adequate waste/wastewater minimisation measures</li> <li>- Adequate general ventilation to minimise accumulation of airborne chemical vapours and VOCs</li> </ul>
17.	Product fabrication	<ul style="list-style-type: none"> <li>- Clean and tidy production areas</li> <li>- Free of fabric scraps</li> </ul>	<p><b>Look out for:</b></p> <ul style="list-style-type: none"> <li>- Fabric scraps on production floor areas</li> </ul> <p><b>Cleaner Production Opportunities:</b></p> <ul style="list-style-type: none"> <li>- Good housekeeping</li> </ul>

# APPENDIX 2

## Recoding Worksheet for Good Housekeeping and Cleaner Production

Name of Factory : .....

Address : .....

Inspection Date : .....

Inspection Time : .....

### EVIDENCE

- Photos (P)
- Factory Records (FR)
- Samples (S)

### FINDINGS

- S : Satisfactory
- US : Unsatisfactory
- F : Further Investigation

Please tick [✓] where applicable

INSPECTION AREA	OBSERVATION	EVIDENCE TAKEN	FINDINGS
1. Raw material reception area		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
2. Fibre preparation		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
3. Yarn spinning		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
4. Slashing/ sizing		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
5. Weaving		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
6. Knitting		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
7. Tufting		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
8. Desizing		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
9. Scouring		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
10. Bleaching		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
11. Singeing		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
12. Mercezing		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
13. Heat-setting		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
14. Dyeing		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
15. Printing		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
16. Finishing		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
17. Product fabrication		<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
18. Wastewater Discharge	<input type="checkbox"/> Treated	<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
	<input type="checkbox"/> Untreated	<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
19. Air emissions	<input type="checkbox"/> Treated	<input type="checkbox"/> P <input type="checkbox"/> FR	<input type="checkbox"/> S <input type="checkbox"/> US <input type="checkbox"/> F
	<input type="checkbox"/> Untreated		
20. Scheduled waste disposal			

### DOE Inspector

Name : .....

Designation : .....

# APPENDIX 3

## Inspection Checklist for Regulatory Compliance

FINAL DISCHARGE STATUS	REGULATORY REQUIREMENT	INSPECTION FOCUS
1. Effluent discharge	Compliance with prevailing effluent standards presented in Annex C in accordance with the Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979.	<ul style="list-style-type: none"> <li>• Evidence of monitoring and analysis</li> <li>• Sampling location and frequency</li> <li>• Analytical results</li> <li>• Public complainants</li> </ul>
2. Air emission	Compliance with the relevant provisions of the Environmental Quality (Clean Air) Regulations, 1978	<ul style="list-style-type: none"> <li>• Factory records</li> <li>• Public complainants</li> </ul>

# APPENDIX 4

## Recording Worksheet for Regulatory Compliance

Name of Factory : .....

Address : .....

Inspection Date : .....

Inspection Time : .....

### LEGEND:

C : Compliance  
 NC : Non-compliance  
 F : Further Investigation

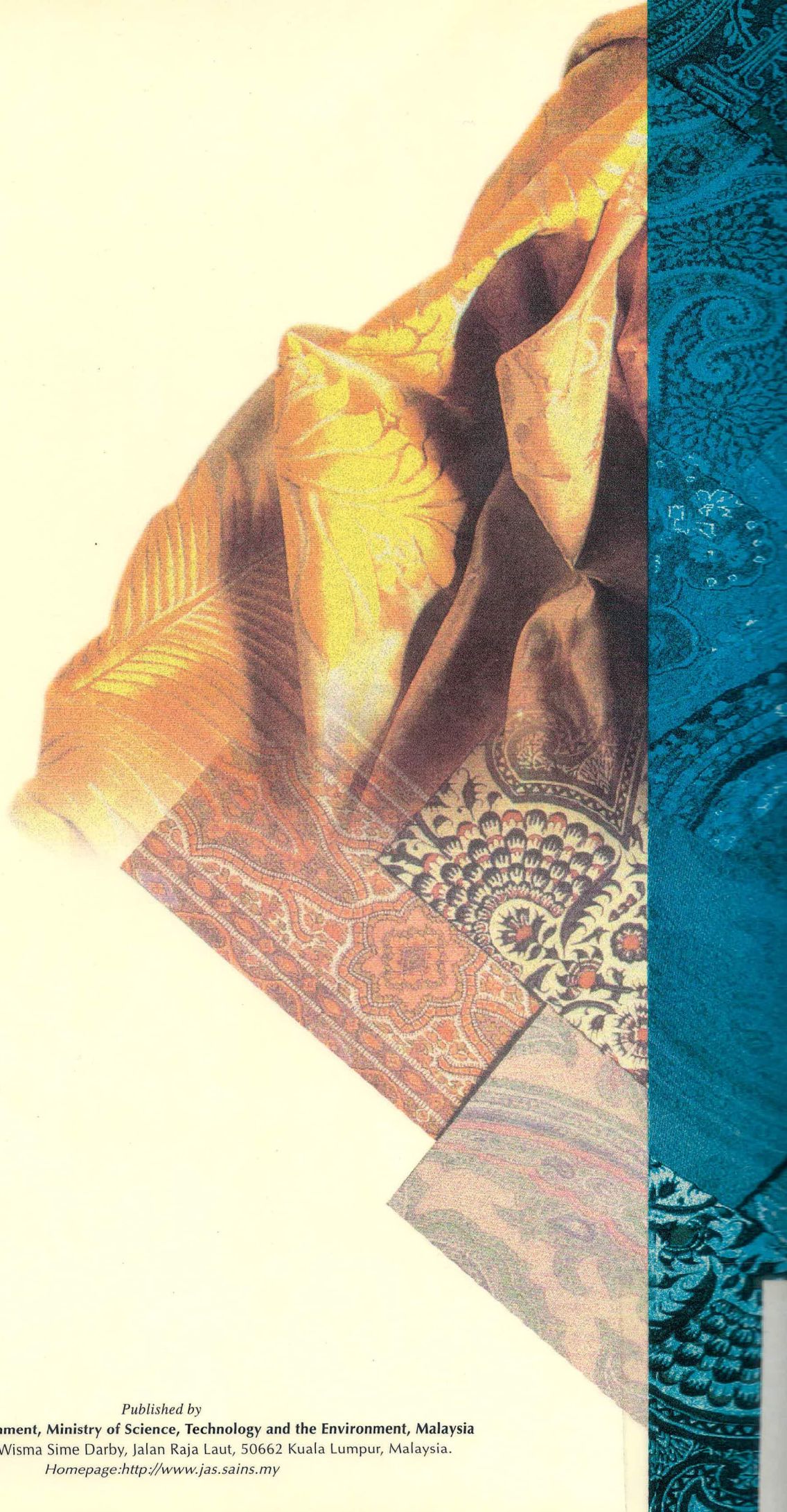
Please tick [✓] where applicable

FINAL DISCHARGE STATUS	INSPECTION FOCUS	EVIDENCE	FINDINGS
1. Effluent Discharge	<ul style="list-style-type: none"> <li>• pH</li> <li>• BOD (3-day; 30°C)</li> <li>• COD</li> <li>• Total solids</li> <li>• Suspended solids</li> <li>• Total Nitrogen</li> <li>• Ammoniacal Nitrogen</li> <li>• Oil &amp; Grease</li> <li>• Temperature</li> <li>• Heavy Metals (specify)</li> </ul>	<input type="checkbox"/> Factory records <input type="checkbox"/> Samples <input type="checkbox"/> Photos	<input type="checkbox"/> C <input type="checkbox"/> NC <input type="checkbox"/> F
2. Air Emission	<ul style="list-style-type: none"> <li>• Scrubbing Systems</li> </ul>	<input type="checkbox"/> Available <input type="checkbox"/> Not available	<input type="checkbox"/> Satisfactory <input type="checkbox"/> Unsatisfactory
3. Solid Waste	<ul style="list-style-type: none"> <li>• Disposal of used packing materials</li> <li>• Sludge treatment plants</li> </ul>	<input type="checkbox"/> Visual inspection <input type="checkbox"/> Photos	<input type="checkbox"/> Satisfactory <input type="checkbox"/> Unsatisfactory
4. Scheduled Wastes	<ul style="list-style-type: none"> <li>• Method of treatment</li> <li>• Ultimate disposal</li> </ul>	<input type="checkbox"/> Visual inspection <input type="checkbox"/> Photos <input type="checkbox"/> Visual inspection <input type="checkbox"/> Photos	<input type="checkbox"/> Satisfactory <input type="checkbox"/> Unsatisfactory <input type="checkbox"/> Satisfactory <input type="checkbox"/> Unsatisfactory

### DOE Inspector

Name : .....

Designation : .....



*Published by*

**Department of Environment, Ministry of Science, Technology and the Environment, Malaysia**

12th & 13th Floor, Wisma Sime Darby, Jalan Raja Laut, 50662 Kuala Lumpur, Malaysia.

*Homepage:* <http://www.jas.sains.my>