PN-ABX-778

Environmental Pollution
Prevention Project

Pollution Prevention In the Textile Industry

Prepared by:

Hagler Bailly Consulting, Inc.
1530 Wilson Boulevard, Suite 900
Arlington, VA 22209-2406
HBI Reference No. TR-95-064

Environmental Pollution Prevention
Project Number 936-5559
Contract Number PCE-5559-C-00-3021-00

August 1995

Sponsored by U.S. Agency for International Development (USAID)

CONTENTS

CHAPTER 1 INTRODUCTION

CHAPTER 2 DESCRIPTION OF RAW MATERIALS, PROCESSES, AND PRODUCTS

CHAPTER 3 SOURCES OF WASTE

CHAPTER 4 POLLUTION PREVENTION STRATEGIES

CHAPTER 5 RECYCLE/REUSE/RECOVERY

CHAPTER 6 POLLUTION PREVENTION OPPORTUNITIES IN THE EGYPTIAN TEXTILE INDUSTRY

APPENDIX I: CASE STUDIES

APPENDIX II: TEXTILES EQUIPMENT VENDORS

CHAPTER 1
INTRODUCTION[1]

1.1 PURPOSE OF MANUAL

This manual provides an introduction to the application of pollution prevention techniques in various textile preparation and finishing processes, including raw materials processing, dry and low water use processes, wet processes, fabric manufacturing, and finishing. Some excerpts from previously prepared manuals on the textile industry as well as other useful references including a list of suitable US vendors or equipment can be found in the appendices.

This is the third manual in a series on the topic of pollution prevention. The first manual, "Pollution Prevention Concepts/Applications", discusses the theory and practice of pollution prevention techniques in general terms. The reader should refer to this manual for general pollution prevention methodologies and definition. The second manual, "Pollution Prevention in Metal Finishing Industries", provides a survey of the application of pollution prevention techniques within the range of metal finishing processes. Additional manuals are planned for the chemical and food industries.

The user of this textile industry manual should view it as a first source in pursuing process and equipment changes in the industry. The manual is intended to assist industry professionals in determining 1) where there might be potential for improving process efficiency and profitability in textile production and finishing facilities, and 2) which alternatives are worthy of consideration for implementation. Users of this manual should not rely on its contents alone to carry out specific measures, but rather seek assistance from experienced professionals in the field such as those listed in the appendices. However, as a general rule of thumb, those process improvement measures which can be implemented at no cost or low cost, or with minimal effort should be considered first, while the more capital and labor intensive options will require more extensive review.

---

[1] This chapter is derived from the following documents:

Environment Canada, *Technical Manual - Waste Abatement, Reuse, Recycle and Reduction Opportunities in Industry*, Waterloo Industrial Waste Management Program, January 1984.

1.2 BACKGROUND

The primary textile industry consists of differing yet inter-related subsectors producing a variety of products, ranging from staple fibers to household products. Each subsector may be viewed as a separate industry, although the output of each stage of production is the major raw material input for the next stage of production. The stages of the textile manufacturing process may involve either dry or wet processing and are briefly outlined below.

Classified by finished product, the textile industry can be divided into the following eight main categories:

- man-made fibers and yarns
- cotton and wool yarns
- cotton, wool and synthetic woven fabrics
- knitted fabrics and goods
- industrial fabric and felts
- floor covers
- domestic products (e.g. blankets and towels)
- cordage, rope and twine

Viewed in terms of manufacturing process, the textile-making industry can be divided into four main stages; 1) yarn production; 2) weaving, knitting, and tufting; 3) fabric finishing; and 4) fabrication of textile products.

Yarn production involves the preparation of both natural and synthetic fibers, although scoured raw wool and cotton fibre are imported for separate processing and blending. Fabric is produced through the weaving, knitting or tufting of yarn. Mostly, yarn is shipped to weaving or knitting mills which produce broad-woven or knitted fabrics, from which familiar textile products are made. Textile yarns can also be tufted into floor coverings such as carpets or rugs. The third stage of the textile process is finishing. Weavers and knitters either do their own dying or pass the textiles on to a dyer. The final stage in the textile manufacturing process is the fabrication of the finished cloth into a number of products.

1.3 WASTE CHARACTERISTICS

Virtually all wastewater is generated in the finishing stage, with small amounts discharged during scouring operations or tarn treatment operations in the yarn production stage. Throughout the entire textile industry, wastewaters are variable in quantity and composition. The main components of wastewater include natural impurities in natural fibers and process chemicals added to treat fibers, yarns or fabrics.

Textile processing plants use a wide variety of dyes and other chemicals, including acids, bases, salts, wetting agents, dyes, and other auxiliary finishes. Many of these are not retained in the final textile product but are discarded after a specific use. Combined textile plant effluent, may therefore, contain any or all of these compounds. Since many textile processes are handled on a batch basis, concentrations of waste materials can fluctuate widely. Some processes require highly acid conditions while others are highly alkaline. Consequently, wastewater pH can also vary greatly over a period of time.

CHAPTER 2
DESCRIPTION OF RAW MATERIALS, PROCESSES, AND PRODUCTS[1]

The textile industry consists of facilities engaged in various processing operations which transform fiber, the industry's basic raw material, into yarn, fabric or other finished textile products. In the U.S., approximately 70 percent of the facilities perform manufacturing operations that require no process water and an additional 10 percent use only small quantities of process water. In contrast, the remaining 20 percent of the facilities that scour wool fibers, clean and condition other natural and man-made fibers and dye or finish various textile products, generally require large quantities of process water. The remainder of this chapter discusses the principal raw materials utilized by the industry, final products manufactured by the industry, and the processing operations required to manufacture those products. Emphasis is placed on operations and products requiring large quantities of process water.

2.1 RAW MATERIALS

A variety of natural and man-made fibers are used in the manufacture of textiles. Presently, wool, cotton and various man-made fibers (e.g., nylon, polyesters and rayon) are the basic fibers used.

The term "synthetic" often is used synonymously with the term"man-made" when referring to fiber. There is however, a technical distinction. As shown in Exhibit 2-1, man-made fibers consist of two major groups: the synthetic fibers (noncellulosic)and the natural polymers (regenerated) group. Synthetic fibers are usually synthesized from simple monomers while natural polymer fibers are manufactured from naturally occurring raw materials. The major portion of the man-made fibers produced are synthetic fibers, with a lesser amount of regenerated fibers produced. Because the term "synthetic" commonly is used to refer to all man-made fibers, this terminology has been adopted for this document.

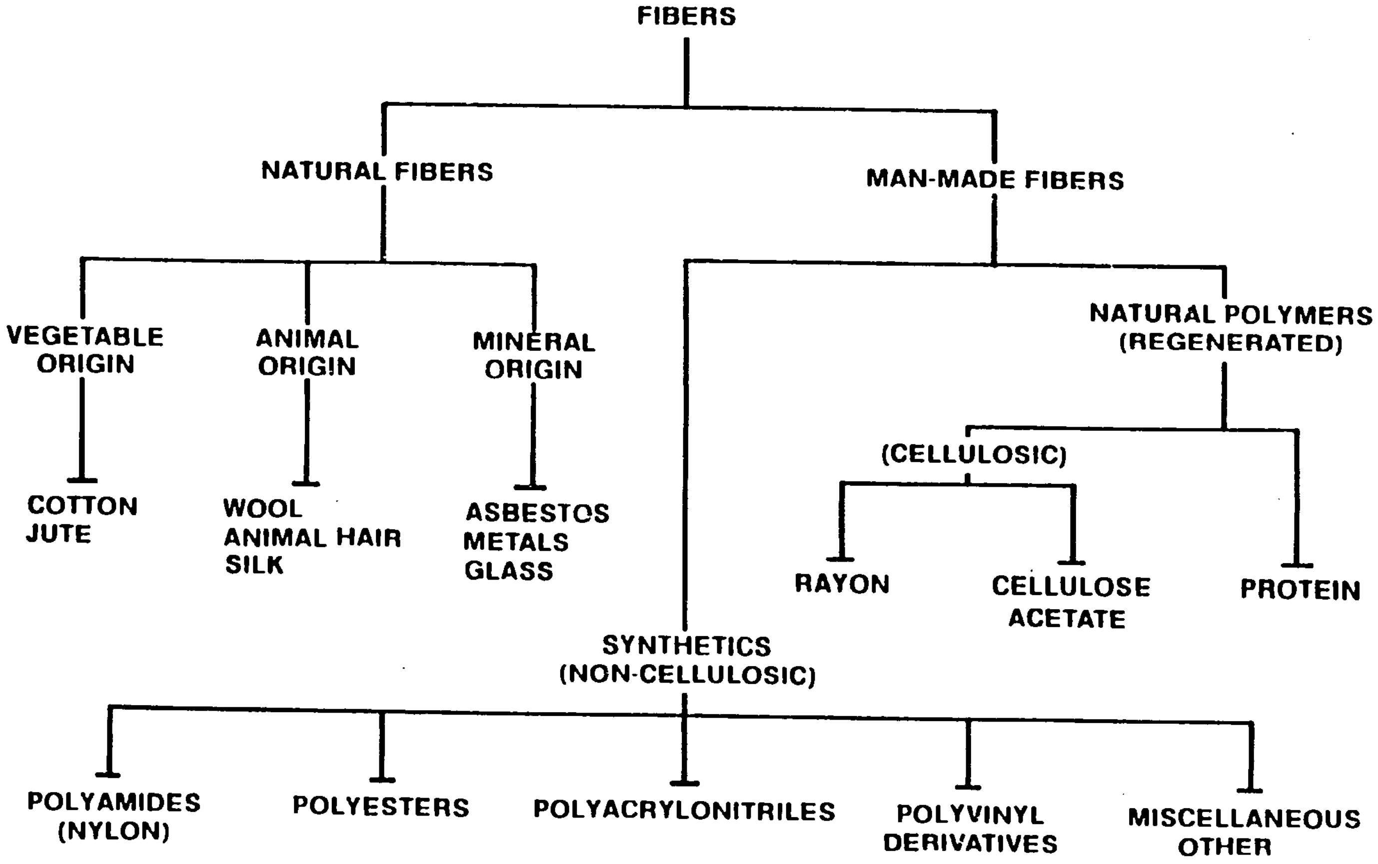
---

[1] This is chapter is derived from the following documents:

Source Reduction Research Partnership, *Textiles Manufacture - Source Reduction of Chlorinated Solvents*, prepared for California Department of Toxic Substances Control and the USEPA Office of Research and Development Risk Reduction Engineering Laboratory, June 1991.

United States Environmental Protection Agency, *Development Document for Effluent Limitations Guidelines and Standards for the Textile Mills - Point Source Category*, EPA 440/1-82/022, September 1982.

Exhibit 2-1
Fibers Used in the Manufacture of Textiles



Cotton and wool are supplied in staple (short fiber) form while the synthetic fibers are supplied as either staple or continuous filament. The steps required to prepare these fibers for processing are dependent on fiber type.

2.1.1 Wool

Raw wool, depending on the breed and habitat of the sheep from which it is obtained, may contain from 30 to 70 percent natural and acquired impurities such as grease, soluble salts (suint) and dirt.

Thorough scouring of this fiber prior to spinning and other processing is necessary, and there are a number of mills in the industry that perform this function only.

2.1.2 Cotton

Consumption of cotton exceeded that of any other single fiber in 1977. Cotton is a much cleaner raw fiber than wool and initial fiber preparation consists only of dry operations such as opening, picking, carding, combing and drawing to mechanically remove vegetable matter and other impurities and to align the fibers for spinning.

2.1.3 Synthetics

Synthetic fibers are typically divided into non-cellulosic and cellulosic fibers. Non-cellulosic fibers, including nylon (polyamides), acrylics, modacrylics and particularly polyester, are used more extensively than cellulosic fibers. Major cellulosic fibers are rayon and cellulose acetate. Synthetic fibers are much cleaner than cotton fibers, eliminating the need for the extensive dry fiber preparation processes used with cotton.

2.2 MAJOR DRY OR LOW WATER USE PROCESSES

Depending on the primary fiber type, a variety of production processes are used to manufacture the various products of this industry. In general, the dry or low water use processing operations precede the wet processing operations in the manufacturing sequence.

2.2.1 Spinning

Spinning is the process by which fiber is converted into yarn or thread. It is performed after initial fiber preparation and consists of drawing out the fibers, twisting them into yarn and winding the newly made yarn onto a bobbin, cone or other suitable holder. This process is completely dry. Texturizing (modification of physical and surface properties of yarn by mechanical or chemical means) also may be performed during yarn manufacture. Some yarn is dyed and finished as a final consumer product; however, most manufactured yarn is used within the industry for tufting, knitting, weaving or other fabric manufacturing.

2.2.2 Tufting

Mechanical tufting is the predominant method of manufacturing carpet. It is performed on large, vertically positioned needle punch machines (tufting machines) that have hundreds of needles in a horizontal bank. Multiple ends of yarn are fed to the bank of needles and the needles pull or loop the yarns through a woven or nonwoven backing material, usually made of polypropylene or jute. The backing moves relative to the needles to anchor each stitch, and the result is loops that form the carpet pile. If the loops are cut during the tufting process, the construction is known as cut pile rather than loop pile. Tufting is a completely dry operation.

2.2.3 Knitting

Knitting is a major method for manufacturing fabrics. Nearly all hosiery is knit, as well as large amounts of piece goods, outerwear and underwear. Knitting is accomplished by interlocking series of loops of one or more yarns using any of a number of popular stitches and is performed with sophisticated, high-speed machinery. Although knitting is a completely dry process, oils usually are applied to the yarn to provide lubrication during stitching. These oils are removed in subsequent wet processing and enter the wastewater stream.

2.2.4 Weaving

Weaving is the most common method of producing fabrics in the textile industry, and woven fabrics are used in the manufacture of numerous consumer and industrial products. Weaving is performed on any of a number of types of looms which, generally speaking, cause lengthwise yarns (warp yarns) to interlace with yarns running at right angles (filling yarns) by going over and under the filling yarns. A special type of shuttleless loom, known as a water jet loom, uses a jet of water to propel the filling yarn. Similarly, an air jet loom, which is a new weaving technology, uses sequential pulses of air to propel the filling yarn. With the exception of water jet looms, weaving is a dry operation. However, to prevent warp yarn breakage caused by friction during the weaving operation, a processing step known as slashing usually is necessary and a small amount of wastewater may be generated as a result.

2.2.5 Slashing

Slashing consists of coating warp yarns with sizing compounds to impart tensile strength and smoothness and thus prevent yarn rupture. It is performed by dipping the yarns through a box or trough containing the sizing agent. This size is dried on the yarn and remains until removed in subsequent operations at a finishing mill. As a result of slashing, the woven fabric may contain add-ons (sizing compounds) equivalent to as much as 15 percent of the weight of the fabric. The most common sizing agents are starch, polyvinyl alcohol (PVA), carboxymethyl cellulose (CMC) and polyacrylic acid (PM). Starch traditionally is associated with the sizing of cotton. Slashing may generate occasional wastewater discharges, usually because of spillage and the cleaning of slasher boxes, rolls and size makeup tanks.

2.3 OTHER FABRIC MANUFACTURING

Two other general fabric manufacturing methods, in addition to the methods previously described, are felted fabric manufacturing and nonwoven fabric manufacturing. These manufacturing methods do not involve the use of yarn. Instead they involve the direct use of fiber to form a web or continuous sheet of fibers. The differences between felts and nonwovens are in the types of fibers used and in the methods of bonding the fibers together into a fabric.

Traditionally, felt has been made of wool, with manufacture based on the ability of the scaly structured wool fibers to felt, or adhere, together naturally. Although use of wool in felts is still common, the use of synthetics (mostly rayon and polyester) has increased in recent years. Felts are made by physically interlocking the fibers through a combination of mechanical action, chemical action, moisture and heat.

Nonwovens, or webbed textiles as they are sometimes called, are used in numerous applications, with more uses being discovered as the relatively new industry expands. They are made of fibers held together by an applied bonding agent or by the fusing of self-bonding thermoplastic fibers. This results in a fabric structure built up from a web or continuous mat of fibers. Although a number of methods are used to form the web and accomplish bonding of the fibers, certain operations are basic to all methods of nonwoven fabric manufacture. These include, in sequence: (1) preparation of the fiber; (2) web formation; (3) web bonding; (4) drying; and (5) finishing techniques.

Web formation usually is accomplished by overlaying several layers of carded fiber or, in the case of thermal processing, randomly laying down filament. A less common method of web formation, called "wet lay," uses water as a transport medium for the fibers. The fibers, suspended in the water, are deposited onto a screen, and a web that is carried from the screen by a large moving belt is formed. Once a nonwoven web is formed, by any method, bonding usually is achieved by roller padding, dipping or spraying with adhesives such as acrylic or polyvinyl acetate resins. A less common bonding method, applicable only to low melting point fibers, is to fuse the fibers together thermally.

2.3.1 Adhesive Products Processing

Adhesive product processes include operations such as bonding, laminating, coating and flocking. These processes are similar in that an adhesive or other continuous coating is applied to a fabric or carpet in order to change the original properties. These processes are completely dry or extremely low in water use, although discharge of the bonding and adhesive chemicals (often latex compounds) or coating materials (often polyvinyl chloride) may result from overspraying, spillage, rinsing and equipment cleanup. Brief descriptions of the most prevalent adhesive product processes follow.

Bonding joins two textile materials together permanently by application of a thin adhesive layer. The process enables different fabric constructions, colors and textures to be combined so that performance, appearance and use are extended. Fabric-to-fabric bonding frequently is performed using either a wet adhesive (often a water based acrylic compound) or urethane foam. In wet adhesive bonding, the underside of the first fabric is coated with adhesive and the second fabric is joined by passing both fabrics through rollers. The adhesive is cured with heat to effect a permanent bond. In foam flame bonding, a layer of urethane foam is passed over a gas flame to make it tacky on one side. The foam and the first fabric then are joined as they pass through rollers. The second fabric can be joined to the other side of the foam layer by repeating the process.

Laminating is similar to bonding except that laminated goods generally consist of foam or nontextile materials bonded to fabrics, or thick layers of foam bonded to two fabrics. Carpet backing, performed to secure the yarns and impart dimensional stability, is a specialized laminating process. It is achieved by bonding a foamed latex or jute backing to the underside of the carpet Latex adhesives typically are used in both cases. An alternative to latex adhesives is the application of a hot melt (thermoplastic) composition.

Fabric coating is an adhesive process that uses various chemicals and synthetic resins to form a relatively distinct, continuous film on a base fabric. Polyvinyl chloride (PVC) is the most common coating for textile fabrics. The coatings may be applied as a 100 percent "active solids" system either as plastisols (dispersions of polymer particles in liquid plasticizers) or as melts (flexible grade polymer plus plasticizer). The plastisols generally are applied by knife over roll coaters; and the melts are applied by calenders (rollers). Although coatings of PVC plastisols and melts are the most common, other substances and methods also may be used for various reasons. One important process is the application of latex coating to tire cord fabric. The loosely woven tire cord fabric is dipped and coated with latex so that the fabric will bond securely with rubber during the manufacture of tires.

Flocking is an adhesive process in which short chopped fibers are applied to an adhesive pattern that has been "preprinted" on a fabric. In this manner, design areas can be produced on any type of fabric to resemble embroidery or woven clipped figures. The process is achieved by spray or electrostatic techniques.

2.3.2 Functional Finishing

Functional finishing refers to the application of a large group of chemical treatments that extend the function of a fabric by providing it with desirable properties. Special finishes can be applied to make a fabric wrinkle resistant, crease retentive, water repellent, flame resistant, mothproof, mildew resistant bacteriostatic and stain resistant. Although the range of chemicals used is broad, the wastewater generated during application usually is relatively small. The finishes often are applied to the fabric from a water solution. It is possible to apply several finishes from a single bath. Application is by means of calenders that transport the finish from a trough to a roll to the surface of the fabric. The finish then is dried and cured onto the fabric. The wastewater sources are bath dumps and cleanup of applicator equipment and mix tanks.

Wrinkle resistance and crease retention (permanent press) are achieved by treating the fabric with synthetic resins. The resins are adhesive in nature and are permanently cross-linked with the fiber molecules. Durability is achieved by curing with heat and a catalyst, resulting in a reaction called polymerization. The actual physical structure of the fabric is changed and the fabric is said to have obtained a "permanent memory" of its flat, finished state.

Water repellency is achieved by treating the fabric with silicones and other synthetic materials. Insoluble soaps and wax emulsions have been used in the past, but these materials lack permanency. If properly applied, the silicone treatments can stand repeated washings or dry cleanings. In addition to water, the silicones successfully repel oily fluids.

Flame resistant finishes are applied to cellulosic fabrics to prevent them from supporting combustion. Phosphorus is a component of most flame retardants, as it is theorized that oxides of phosphorus combine with water formed at high temperatures to restrict the production of combustible gases. Tetrakis (hydroxy methyl) phosphonium chloride (THPC) is the essential ingredient of many flame retardant formulations.

Mothproofing finishes typically are applied to wool and other animal hair fibers. Fabric made from these fibers are impregnated with chemicals that make the fabric unfit as food for the moth larva. Chemicals such as silicofluoride and chromium fluoride are used in the formulations.

The growth of mildew, mold, fungus and rot is inhibited by application of biocides that destroy their growth. Commonly used compounds contain chlorinated phenols or metallic salts of zinc, copper or mercury. Hygienic additives also are used to inhibit the growth of bacteria. These additives prevent odors, prolong the life of the fabric and also combat mildew, mold and fungus.

Soil release finishes make it possible to remove stains from fabrics by ordinary washing. Most of the finishes use organosilicone compounds that are applied by the pad-dry-cure process. Other soil release finishes in use contain fluorocompounds or oxazoline derivatives. Soil release finishes produce a hydrophilic state in the fabric and thus make polyester and polyester blend fabrics less conducive to static collection.

In addition to functional finishing processes, there are a number of mechanical finishing operations such as calendering, embossing and napping that change the surface effect of fabric by means of rollers, pressure, heat or similar actions. These processes can be performed before or after the chemical treatment but do not result in wastewater.

2.4 MAJOR WET PROCESSES

Most high water use textile manufacturing processes involve the conventional finishing of fiber and fabric products. The most significant processes are desizing, scouring, mercerizing, bleaching, dyeing and printing. In the case of wool products, the distinct nature of this fiber often makes additional wet processing necessary prior to conventional finishing. Additional specific processes for wool include raw wool scouring, carbonizing and fulling.

Although the various wet processes are described separately, it is not uncommon for two or more operations to occur sequentially in a single batch unit or on a continuous range. For example, it is common for desizing, scouring and mercerizing operations to be placed in tandem with the continuous bleaching range to finish cotton more efficiently. A variety of wet finishing situations of this type may occur, depending upon factors such as processes used, type and quality of materials and product and original mill and equipment design.

2.4.1 Raw Wool Scouring

Wool scouring is the first treatment performed on wool and is employed to remove the impurities peculiar to wool fibers. These impurities are present in great quantities and variety in raw wool and include natural wool grease and sweat and acquired impurities such as dirt, feces and vegetable matter. Disinfectants and insecticides applied in sheep dips for therapeutic purposes also may be present. Most of the natural and acquired impurities in wool are removed in the scouring process.

Two methods of wool scouring, solvent and detergent, are practiced in the U. S., although detergent scouring is used almost exclusively. In the detergent process, the wool is raked through a series of 5,700 to 11,400 liter (1,500 to 3,000 gallons) scouring bowls known as a

\\

"scouring train." Unless the first bowl is used as a steeping or desuinting bowl, the first two bowls contain varying concentrations of either soap and alkali, or nonionic detergents of the ethylene oxide condensate class. The soap-alkali scouring baths are generally at a temperature of 46° to 54°C (115° to 130°F) and a pH of 9.5 to 10.5; neutral detergent baths normally have a pH of 6.5 to 7.5 and a temperature of 57° to 71°C (135° to 160°F). The last two bowls of the scouring train are for rinsing and a counterflow arrangement usually is employed using the relatively clean waters from these bowls in preceding bowls.

Scouring emulsifies the dirt and grease and produces a brown, gritty, turbid waste that often is covered with a greasy scum. It is estimated that for every pound of fibers obtained, one and one-half pounds of waste impurities are produced. Because the wool grease present in the scour liquor is not readily biodegradable and is of commercial value, grease recovery usually is practiced. In the most typical recovery process, the scour liquor first is piped to a separation tank where settling of grit and dirt occurs. The supernatant from the tank then is centrifuged (one or more stages) into high density, medium density and low density streams. The high density stream consists mainly of dirt and grit, and is discharged as waste. The medium density stream is recycled to the wool scouring train. The low density stream contains concentrated grease that normally is refined further to produce lanolin. Acid cracking, utilizing sulfuric acid and heat, is an alternative method of grease recovery, but it is not practiced widely at this time.

2.4.2 Carbonizing

Carbonizing removes burrs and other vegetable matter from loose wool or woven wool goods. These cellulosic impurities may be degraded to hydrocellulose, without damaging the wool, when acted on by acids. It is important to remove these impurities from the wool to prevent unequal absorption of dyes.

The first operation in carbonization is acid impregnation. Typically, this step consists of soaking the wool in a 4 to 7 percent solution of sulfuric acid for a period of 2 to 3 hours. The excess acid is squeezed out and the wool is baked to oxidize the cellulosic contaminants to gases and a solid carbon residue. The charred material, primarily hydrocellulose, is crushed between pressure rollers so that it may be shaken out by mechanical agitation. Some solid waste is generated but, with the exception of an occasional dump of contaminated acid bath, no liquid waste results. However, after the residue has been shaken out, the acid must be removed. This is achieved by preliminary rinsing to remove most of the acid followed by neutralization with sodium carbonate solution. A final rinse is used to remove residual alkali. As a result, the overall water requirements for the carbonization of wool are substantial.

2.4.3 Fulling

Fulling gives woven woolen cloth a thick, compact and substantial feel, finish and appearance. To accomplish it, the cloth is mechanically worked in fulling machines in the presence of heat, moisture and sometimes pressure. This allows the fibers to felt together, which causes shrinkage, increases the weight and obscures the woven threads of the cloth.

There are two common methods of fulling, alkali and acid. In alkali fulling, soap or detergent provides the needed lubrication and moisture for proper felting action. The soap or detergent usually is mixed with sodium carbonate and a sequestering agent in a concentrated solution. In acid fulling, which can be used to prevent bleeding of color, an aqueous solution of sulfuric acid, hydrogen peroxide and a small amount of a metallic catalyst (chromium, copper or cobalt) is used.

The first step in both methods is to impregnate the fabric in the fulling machines with heated fulling solution. If acid fulling is performed, it is followed by alkali fulling. No waste is produced during this step because all of the solution is absorbed by the cloth. At this point, 10 to 25 percent of the fabric weight may be process chemicals such as soap, alkali, sequesterant and carding oil. Fulling is followed by extensive washing to remove process chemicals and prevent rancidity and wool spoilage. The usual washing procedure is to subject the fulled cloth to two soapings, two warm rinses and one cold rinse. The first soaping usually is achieved by agitation of the fabric in the soapy solution created by the fulling soap already on the cloth. After a warm rinse, the cloth usually is soaped a second time in a stationary bath with a two percent solution of soap or synthetic detergent. This step is followed by a second warm rinse at 40°C (105°F) and a cold rinse to cool the cloth.

2.4.4 Desizing

Desizing removes the sizing compounds applied to yarn in the slashing operation and is usually the first wet finishing operation performed on woven fabric. It consists of solubilizing the size with mineral acid or enzymes (starch size only) and thoroughly washing the fabric. Acid desizing uses a solution of dilute sulfuric acid to hydrolyze the starch and render it water soluble. Enzyme desizing uses vegetable or animal enzymes to decompose starches to a water soluble form. In either case, the desizing agent normally is applied to the fabric by roller pad. After the desizing solution has been applied, the goods are soaked or steeped in storage bins, steamers or J-boxes. After the size has been solubilized, the solution is discarded and the fabric is washed and rinsed. For desizing of PVA and CMC, sizing materials that are directly soluble in water, no decomposition is required and the goods are washed only with water.

13

2.4.5 Scouring

Scouring is employed to remove natural and acquired impurities from fibers and fabric. The nature of the scouring operation depends on the fiber type. Raw wool scouring has been discussed separately because of its uniqueness among textile processes. Synthetic fiber scouring is milder than scouring of cotton fiber because of the smaller amount of impurities present.

Cotton fabric contains natural impurities such as wax, pectins and alcohols, as well as processing impurities such as size, dirt and oil. These substances are removed from the fabric by hot alkaline detergents or soap solutions. Also cotton scouring makes the fibers whiter and more absorbent for subsequent bleaching and dyeing. Scouring of cotton often is done in conjunction with desizing rather than as a totally separate operation and usually is accomplished by either kier or open width boiling.

In kier boiling, desized cotton fabric in rope form is loaded into a large cylindrical pressure vessel. An aqueous solution of sodium hydroxide, soap and sodium silicate, or a similar mixture, is recirculated through the goods at temperatures up to 104°C (220°F), pH values of 10 to 13, and pressures of 0.70 to 1.41kg/sq cm (10 to 20 psig) for 6 to 12 hours. The fabric then is cooled and rinsed in the kier. Goods processed in the open width normally are scoured in open width boil-out machines, also known as progressive jigs. The goods are fed continuously through the scouring solution by the use of transfer rolls, and after the required contact period, are unrolled through wash boxes. Methods of scouring and dumping the scour waste vary from mill to mill, but at all mills the cloth is rinsed completely to clean the fibers and remove residual alkali. Either light or heavy scouring of wool goods may be performed during wool finishing to remove acquired impurities.

2.4.6 Special Scouring

The manufacture of synthetic fibers is well controlled and the fibers are relatively free of impurities. Consequently, only light scouring and little or no bleaching is required prior to dyeing. Sizes and lubricating oils applied to synthetics usually are removed in a special scouring process rather than in a separate desizing step. Scour baths usually contain weak alkalis, antistatic agents, lubricants, soap or detergents, and special scouring agents such as ethoxylated phenols and other emulsifiers. Optical brighteners, which function in a capacity similar to dyes, often are applied to a fabric during the special scouring process. The optical brighteners function to absorb ultraviolet rays and reflect certain wavelengths of visible light, which in turn add brightness to the color of the fabric.

Although acetate fibers may be scoured and dyed in one bath, most synthetics are scoured independently of the dyeing operation. Rope soapers, jig scours, beck scours, drum or paddle scours or beam dyeing equipment may be used. After scouring, the goods are rinsed to remove excess material in preparation for the dye bath.

2.4.7 Solvent Scouring

Fabric scouring, where chlorinated solvents are used, is performed to remove foreign substances such as remaining on textile fiber during production of the fabric. In the case of cotton, the natural wax and the starch introduced during the sizing operation need to be removed. The continuous dying processes, which are now used, allow only a short time of contact of the cloth with the dye liquid, and hence the cloth must be prepared so as to absorb rapidly and adequately. In addition, scouring can lighten the color and remove motes and non-cellulosic impurities which may spoil the appearance of finished cloth.

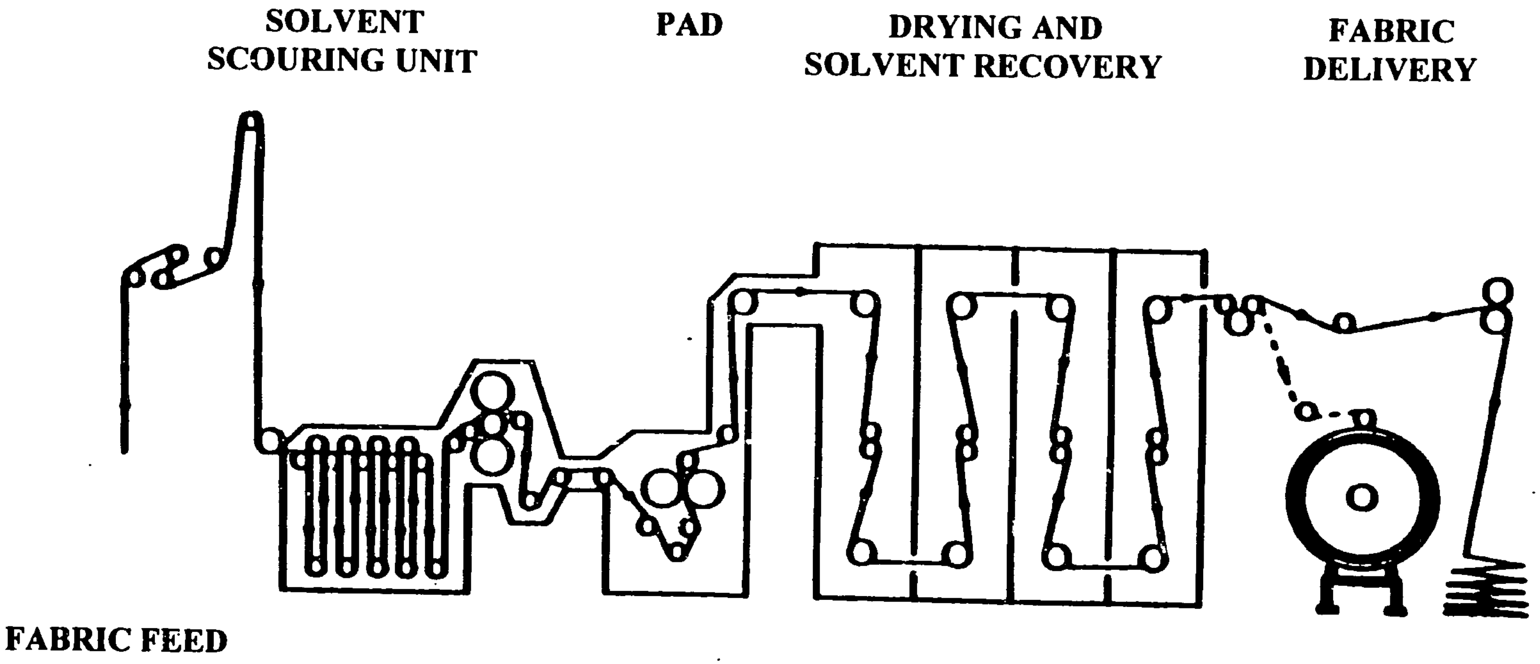
Fabric may be scoured in open width or rope form by applying a solution of caustic, some solvent to remove waxes from man-made and some blended fabrics, or a suitable detergent, and allowing adequate retention time for the solution to remove impurities from the fabric. The fabric is then washed in hot water (approximately 140 degrees F) to remove the scouring solution, only when caustic and detergent solution are used.

There are two solvent processes for scouring textiles: batch and continuous operations. In the batch process, the solvent is heated and the machine has a system to hold clean solvent, rinse liquor and finished liquors in four to six tanks. The fabric is contained in a perforated drum that rotates in the solvent which is being circulated through the drum. The solvent liquors are removed from the fabric by centrifugation. Fabrics are dried by hot air circulation and solvent is recovered by condensation and carbon adsorption. Contaminated liquid solvent is recycled on-site by distillation.

A continuous solvent scouring is depicted in Exhibit 2-2. Fabric is fed on roller to the scouring unit. Here the fabric is dipped or sprayed with cold solvent, or immersed in solvent vapor. Following the scouring process, the fabric is wrung and fed to the drying operation. The solvent vapors from the drying operations are condensed and recovered. The spent solvent and the condensate are distilled and reused. Following drying, the fabric is folded, rolled, or sent to a dyeing process. Generally, during the scouring operation, the fabric is supported and tensionless.

During solvent scouring, hydrochloric acid can be formed in the fiber. A 5 to 10 percent moisture content is common in fibers, particularly cotton and polyester/cotton fabrics and this moisture can react with the solvent, forming hydrochloric acid. The solvent remaining in the fabric cannot be completely recovered. About eight percent of the solvent remains in the fabric. The ratio of solvent consumption to fabric in pounds is about one to 10. That is for every 10 pounds of fabric, approximately one pound of solvent is lost.

Exhibit 2-2
Continuous Solvent Scouring



No solvent scouring equipment is manufactured in the U.S. today. CFC-113 full machines are manufactured in Switzerland and Germany, and PERC machines are manufactured in Italy as well as Germany.

CFC-113 is reported to have some advantage over PERC in scouring. The oil recovered by distillation as a part of the scouring process can sometimes be directly reused for sizing of yarns, if the plant employs such processes. Otherwise, it can be mixed with other high BTU oils and sent off-site to a cement kiln or a resource recovery facility. The oil recovered from PERC scouring would commonly contain some PERC residue (because of PERC's high boiling point) and cannot be reused for sizing operations.

CFC-113 can be an effective scouring agent in Permasol F machines. Residual oil levels of 0.05 to 0.3 percent generally can be achieved using CFC-113. Scouring of polyester fabrics with PERC can also be very effective. It can reduce initial oil content of 4 percent to residual oil content of 0.05 to 0.3 percent.

Some types of fibers that are not commonly solvent scoured are cotton and cotton synthetic blends, although solvent scour patent of cotton fabric exists. In processing cotton fabrics, the cloth may be kier scoured (boiled) in a caustic bath to remove any unwanted impurities. In the patented process, cotton goods can be scoured with an aqueous emulsion of an alkaline compound in a chlorinated solvent. The formulation contains between 40 and 99.5 percent water and 0.5 to about 60 percent of alkaline compound.

Some processes that may use solvents for scouring are finishing of 100 percent synthetics, bast fibers, glass, silk, and metallic fiber. Occasionally fabrics made of wool and other animal hair fibers or blends of wool and synthetics (both woven and knit) are solvent scoured, using PERC or CFC-113.

Scouring of raw wool has been a concern because of the 30 to 50 percent non-wool impurities which have to be remove before processing. Compositions of these impurities are quite complex and may be divided into the following components: wool wax or lanolin, water soluble material (suint) including dried sweat, urine and protein degradation products, and insoluble particulate material including sand, soil, vegetable and fecal matter. Not only PERC, but other hydrocarbon solvents such as kerosene, hexane and petroleum distillates have been used in scouring of raw wool material.

Scouring of knit fabrics can also be accomplished by solvent scouring. Solvent scouring of synthetic knits has been used in other countries but has not found widespread application in the United States. The solvent used is PERC or CFC-113 and the equipment must be airtight to prevent air pollution and the escape of the expensive or regulated solvent. The solvent may be applied by either high velocity jets or by an immersion method. The process has the advantages that the wastewater load from the scouring operation in eliminated and the cost and energy consumption of subsequent fabric drying operations are significantly reduced. However, solvent purchase costs are high in scouring operations and the use of some solvents can present a worker exposure hazard.

2.4.8 Mercerizing

Mercerization increases the tensile strength, luster, sheen, dye affinity and abrasion resistance of cotton goods. It may be performed on yarn or greige goods, but usually is conducted after fabric scouring. It is accomplished by impregnating the fabric with cold sodium hydroxide solution (15 to 30 percent by volume). The solution causes swelling of the cotton (cellulose) fibers as the alkali is absorbed. Higher concentrations, longer residence times and lower temperatures favor greater swelling. When increased tensile strength is a primary consideration, the fabric is mercerized on a tenter frame. After the desired period of contact, the caustic is washed off thoroughly, sometimes with the aid of an intermediate acid wash. In many mills, the sodium hydroxide is reclaimed in caustic recovery units and concentrated for reuse in scouring or mercerization. It is estimated that less than half of all cotton fabrics are mercerized and, with the increasing use of cotton-polyester blends, less mercerization is likely in the future.

2.4.9 Bleaching

Bleaching is a common finishing process used to whiten cotton, wool and some synthetic fibers. In addition to removing color, bleaching can dissolve sizing, natural pectins, waxes and small particles of foreign matter. It usually is performed immediately after scouring or mercerizing and prior to dyeing or printing. Bins, jigs or continuous equipment may be employed. Bleaching is accomplished primarily with hydrogen peroxide, although hypochlorite, peracetic acid, chlorine dioxide, sodium perborate or even reducing agents may be used.

Most cotton fabrics are bleached on continuous bleaching ranges directly after scouring. The fabric, fed in either rope or open width form, first is washed with hot water to ensure removal of all contaminants. As the goods leave the washer, excess water is removed and sodium hydroxide is added. The saturated fabric remains at about 80° to 82°C (175° to 180°F) for approximately 40 to 60 minutes, resulting in the conversion of fats and waxes to soaps. The material then is rinsed with hot water and passed through a peroxide solution containing hydrogen peroxide and sodium silicate. At this point, the cotton is bleached out at atemperature of 90°C (195°F) for approximately 40 to 60 minutes before the final hot water rinse. A second stage of bleaching, sometimes with sodium hypochlorite, may be used in some mills.

In sodium hypochlorite bleaching whether batch or continuous, the cloth is rinsed, scoured with a weak solution of sulfuric or hydrochloric acid and rinsed again. The cloth then is passed through a solution of sodium hypochlorite and allowed to bleach out in bins (batch) or J-boxes (continuous) for a designated period of time. A final rinse then is performed.

Bleaching methods for synthetic fabrics depend on fiber type. Because there is less coloring matter to remove, cellulosic fibers (rayon and acetate) are bleached using methods similar to, but less extensive than, those used in bleaching cotton. Noncellulosic fibers (polyesters, acrylics, nylons) usually are not bleached unless blended with natural fibers (principally cotton and wool). When bleaching is performed, various weak acids may be used.

Wool top or fabric may be bleached if white or very light colored fabric is required. Hydrogen or sodium peroxide, or optical brighteners composed of various organic compounds may be used. Control of pH is important in peroxide bleaching of wool and usually is achieved by mixing hydrogen peroxide with sodium silicate or sodium peroxide with acid. Optical brighteners are useful in combination with peroxide bleaching agents to help give wool a good white base for subsequent dyeing. Solvent bleaching systems and pressure steamers for reduction of residence time in continuous bleaching are two developments that may change the character of bleaching operations in the future.

2.4.10 Dyeing

Dyeing is the most complex of all the wet processing operations. It is performed essentially for aesthetic reasons in that it does not contribute to the basic structural integrity, wearability or durability of the final product. It does, however, play a major role in the marketability of textile products.

The function of dyeing is to anchor dyestuff molecules to textile fibers. The color observed is a result of the light waves absorbed and reflected by the dyestuffs. The methods of dyeing, the types of dyestuffs and auxiliary chemicals used in dyeing and the types of equipment available and in use for the application of dyes are discussed below.

The mechanisms of dyeing textile fibers can be summarized as follows:

1. Migration of the dye from the solution to the interface, accompanied by adsorption on the surface of the fiber.
2. Diffusion of the dye from the surface towards the center of the fiber.
3. Anchoring of the dye molecules by covalent or hydrogen bonds, or other physical forces.

Dye/fiber interfacing is a function of the type of equipment utilized, while the specific dye formulas provide the chemical conditions for bonding to take place. Dyeing can be performed while the goods (fiber) are in the stock, top (wool or wool blends), yarn or fabric state. Both single and multiple fiber goods can be dyed, although multiple fiber dyeing may require multiple steps.

Stock dyeing is performed before the fiber has been converted to the top or yarn state. In simplest terms, the process involves placing stock fiber in a vat or pressure kettle, applying a sufficient quantity of dye liquor, providing optimum conditions, allowing time for the chemical reaction and rinsing. Wool used to produce fancy goods and a small amount of cotton or synthetic fibers used for flocking are dyed in this manner.

Top dyeing is performed on sliver or slubbing that is wound into a cylindrical shape approximately 46 cm (18 in.) in diameter. The top has been carded and combed but not spun into yarn. Dyeing is accomplished by placing the top in cans, placing the cans in a dye vat, circulating the dye liquor and allowing sufficient time for reaction. Fibers used for worsted fabric usually are dyed in this manner.

Yarn dyeing is performed on yarns that are used for woven goods, knit goods and carpets. The traditional methods are skein (hank), package and space dyeing. Skein dyeing is accomplished by placing turns of yarn on a frame, placing the frame in a dye bath in which either the frame or the dye liquor is circulated, providing optimum conditions, allowing time for reaction and rinsing. Package dyeing is the most common yarn dyeing process and is accomplished by placing yarn wound onto perforated tubes on a frame, placing the frame into a pressure vessel, circulating dye liquor in and out of the cones and yarn under optimum conditions and rinsing. Warp yarns wound on large perforated beams also are dyed using the package method. The beams of dyed yarn can be used directly in weaving.

Package dyeing is favored over skein dyeing because skein-reeling is a comparatively expensive process, more working space is required and the skein-dyed yarn must be wound onto a bobbin, cone or spool at a later stage.

Space dyeing is a specialty yarn dyeing process. The technique resembles the roller printing process discussed below, in that the dye liquor is applied to warp yarns at a repeat or random interval by a roller type dye pad. The dyed yarn then enters a hot water steam box for development and fixation of the color and finally is rinsed. Two or more dyes can be padded. The process is especially important to the manufacture of tufted carpet.

Fabric dyeing is the most common dyeing method in use today. It is preferred over yarn dyeing because it is a continuous or semicontinuous process and because a mill does not have to process large lots to be cost effective. The methods employed include beck (winch) jet, jig and continuous range.

Beck dyeing is accomplished with the fabric in the rope form. Both atmospheric and pressure machines are used. In either case, the fabric, connected end to end, is rotated through dye liquor by passing over a large rotating drum. Twelve or more loops of fabric can be dyed side by side, being kept apart by dividing fingers. The length of each loop is such that the fabric lies in a heap at the bottom of the beck for a short time. The proper conditions and residence time must be provided as in the other previously described methods. Jet dyeing also is accomplished with the fabric in rope form. Jet machines are similar to the pressure becks except that each loop of fabric passes through a venturi tube. A pump circulates the dye liquor through the tubes and the suction at the venturi causes the fabric to rotate. Jet machines have improved on certain deficiencies of beck dyeing by allowing shorter liquor-to-fabric ratios (less dye liquor per unit weight of fabric), reducing the risk of tangling, providing a more uniform temperature, reducing elongation of the fabric caused by tension and lessening the formation of creases in synthetic fabrics. Jet dyeing is especially suitable to synthetic fibers.

Jig dyeing is performed with the fabric in the open width. Both atmospheric and pressure equipment are available. Dyeing is accomplished by slowly winding the fabric over rollers that stand above a shallow trough containing the dye liquors. The rollers, by rotating in clockwise and counterclockwise directions alternately, move the cloth through the dye liquor, complete immersion being insured by guide rollers at the bottom of the trough. Because only a few meters of the fabric are immersed at a time, it is possible to work with an exceedingly short liquor ratio (low dye liquor volume per unit weight of fabric). Jig dyeing is particularly attractive for cellulosic fibers because the dyes used generally do not exhaust well and less dyestuff is wasted.

Continuous dyeing also is performed with the fabric in the open width. It is accomplished under atmospheric conditions on what are termed "continuous dyeing ranges." These ranges generally consist of a number of dip troughs through which the fabric is dyed and oxidized, rinse boxes that remove excess dye liquor and heated rotating drying cans.

Thermosol dyeing is a continuous process used for dyeing polyester, and polyester/cotton blends. Dye is padded onto the fabric in the pigment form from a pad box and dried, causing a film containing the dye to adhere to the surface of the fibers. The fabric then is heated to 190° to 220°C (355° to 430°F) for a period of 30 to 60 seconds to set the dye. The transfer of dye from the surface deposit to the polyester is through the vapor phase.

Dyes are classified according to their chemical constitution or on the basis of their dyeing properties, with little correlation between the two systems. Classification according to application is most relevant and is discussed below.

The following tabulation provides the classification name and the principal fiber types for which the dye classes are used, based on the application classification.

Acid Dyes. These dyes are sodium salts, usually of sulfonic acids , but in a few cases carboxylic acids. They invariably are manufactured as sodium salts because free acid dyes are more difficult to isolate and they are hygroscopic, which makes them difficult to pack and store. Acid dyes have a direct affinity for protein fibers and are the main class of dyes used in wool dyeing. Most will not exhaust on cellulosic fiber but, because acid dyes resemble the direct dyes in chemical constitution, there are a number that dye cellulose quite well. The dyes also have an affinity for polyamide fibers. There are many ways in which the acid dyes are applied. Primarily, the variations create conditions suitable to the type of dye used. In addition to the dyes, the following auxiliary chemicals may be required for satisfactory dyeing:

sodium sulfate (Glauber's salt)
sulfuric acid
formic acid
acetic acid
ammonium acetate
ammonium sulfate
ammonium phosphate
leveling agents

Azoic Dyes. These dyes are insoluble pigments anchored within the fiber by padding with a soluble coupling compound and then treating with a diazotized base or stabilized color salt. Because naphthol is used as the coupling component, azoic dyes are also referred to as naphthol dyes. They are used for dyeing cellulosic fibers when comparatively good water fastness and brightness of shade are required at a reasonable cost. They are especially satisfactory in the yellow, orange and red spectrum. They have been applied to protein fibers, but equally good results can be obtained with acid dyes by simpler methods. Dyeing with azoic dyes is a two-stage process involving impregnating the fiber with an azoic coupling component and coupling with a diazonium salt. There are over 50 coupling components listed in the Color Index (C.I.), and over 50 bases that can be diazotized and coupled with the former (10). In addition to the coupling component and base, common salt and surface-active compounds (sulfated fatty alcohol or ethylene oxide condensate) are usually used to speed the reaction.

Basic Dyes. These dyes are usually hydrochlorides of salts or organic bases. The chromophores are found in the cation; therefore, these dyes often are referred to as cationic dyes. Because of poor fastness to light, these dyes virtually had been discontinued until it was discovered that they would dye acrylic fibers and give bright, clear shades of color which possess good light fastness. Cellulosic fibers have, for all practical purposes, no affinity for basic dyes. The dyes can be

22

applied to cellulose if the fibers are mordanted before dyeing; however, these dyes are rarely applied to cotton in current practice. In the case of protein fiber, there is substantial evidence that the affinity is of a chemical nature.

There are several methods of applying basic dyes to acrylic fibers and many dyes that are suitable. In addition to the dye, the following auxiliary chemicals may be necessary for satisfactory dyeing:

acetic acid
formic acid
oxalic acid
tannic acid
sodium sulfate
sodium acetate
ethylene carbonate

Direct Dyes. These dyes resemble acid dyes in that they are sodium salts of sulfonic acids and are almost invariably azo compounds. They have a direct affinity for cellulosic fibers. These dyes frequently are referred to as substantiative dyes and, in special circumstances, they are used to dye protein fibers. The distinction between acid and direct dyes is often not well-defined. For example, C.I. Direct Dye 37 may be applied as a direct dye to cellulose or as an acid dye to protein fibers. The dyes offer a rather wide range of color; however, their water fastness and light fastness vary depending on shade.

The direct dyes are divided into three classes; self-leveling (Class A), salt controllable (Class B), and temperature controllable (Class C). Depending on the class of the dye used, one or more of the following auxiliary chemicals may be necessary for satisfactory dyeing:

sodium chloride
sequestering agents
sodium sulfate
sodium nitrite
hydrochloric acid
aromatic amines

Disperse Dyes. This class of dyes arose out of the need to find an easy and satisfactory way to dye cellulose acetate. These dyes are suspensions of finely divided organic compounds with very slight aqueous solubility. Hydrophobic fibers, such as secondary or tertiary cellulose acetate, and the synthetic fibers often will dye better with insoluble dyes than those that are dissolved in water.

There are numerous disperse dyes but no sharp dividing lines to group them into separate classifications according to their dyeing behavior. In addition to the dyes, one or more of the following auxiliary chemicals may be necessary for satisfactory dyeing:

acetic acid
dispersing agents
orthophenylphenol
butyl benzoate carriers
chlorobenzene
diethyl phthalate
other carriers

Mordant Dyes. This class of dyes includes many natural and synthetic dyes, the latter usually being obtained from anthracene. These dyes have no natural affinity for textile fibers, but are applied to cellulosic or protein fibers that have been mordanted with a metallic oxide. Because chromium is the most commonly used mordant, these dyes often are referred to as chrome dyes. At one time, there were a number of naturally occurring mordant dyes in use, but acid mordant dyes have replaced these.

The acid mordant dyes are applied to wool or polyamide fibers as if they were acid dyes and, by subsequent mordanting, are given good water fastness. The mordant dyes usually are applied in a boiling acid dye bath and, when exhaustion is complete, an appropriate amount of dichromate is added and the bath boiled for an additional 30 minutes. The following auxiliary chemicals are generally necessary to achieve satisfactory results:

acetic acid
sodium sulfate (Glauber's salt)
penetrating agents
sulfuric or formic acid
potassium or sodium dichromate
ammonium sulfate

Premetallized Dyes. These dyes were developed so wool could be dyed directly without the need for mordanting in an after-treatment step. They are classified as 1:1 and 2:1 metal complex dyes depending on the number of dye molecules present for each metallic atom. Premetallized dyes are quicker to apply, easier to match, and for some colors, brighter than mordant dyes.

The premetallized dyes are applied like acid mordant dyes in a boiling acid dye bath. In addition to the dyes, the following auxiliary chemicals are necessary to achieve satisfactory results:

24

sulfuric acid
sodium sulfate
leveling agent

Reactive Dyes. These are the latest dyestuff discovery and, because they react chemically with cotton, viscose, linen, wool and silk, they possess very good water fastness. They can be dyed by many methods and adapt well to the requirements of continuous dyeing. The whole spectrum of color can be applied with these dyes.

There are several classes of reactive dyes that are specific to the fibers being processed. In addition to the dyes, one or more of the following auxiliary chemicals may be necessary for satisfactory dyeing:

sodium chloride
urea
sodium carbonate
sodium hydroxide
trisodium phosphate
tetrasodium pyrophosphate

Sulfur Dyes. These dyes are complex organic compounds that contain sulfur linkages within the molecules. Sulfur dyes usually are insoluble in water, but dissolve in a solution of sodium sulfide to which sodium carbonate may be added. The sodium sulfide acts as a reducing agent, severing the sulfide linkage and breaking down the molecules into simpler components that are soluble in water and have an affinity toward cellulose. The soluble components then are oxidized in the fiber to the original insoluble sulfur dyes. These dyes have excellent resistance to washing, but poor resistance to sunlight. Sulfur dyes will dye cotton, linen and rayon, but the colors are not very bright.

In the reduced state, the dyeing properties of the sulfur dyes resemble those of the direct dyes. These dyes exhaust better in the presence of electrolytes and vary considerably with regard to the temperatures at which maximum exhaustion takes place. Sulfur dyes are decomposed by acids, usually with the liberation of hydrogen sulfide, and when exposed to air or acted upon by mild oxidizing agents, some of the sulfur is oxidized to sulfuric acid. In addition to the dyes, one or more of the following auxiliary chemicals may be necessary for satisfactory dyeing:

sodium sulfide
sodium carbonate
sodium dichromate
acetic or alternative acids

hydrogen peroxide
sodium chloride
sodium sulfate
copper sulfate

Vat Dyes. These are the best known dyes in use today because of all-around fastness to both washing and sunlight. Vat dyes are among the oldest natural coloring matters used for textiles. These dyes are insoluble in water and cannot be used without modification. When treated with reducing agents, vat dyes are converted into leuco (combining) compounds, all of which are soluble in water in the presence of alkali. The leuco compounds have an affinity for cellulose and reoxidize to the insoluble colored pigment within the fiber when exposed to air. Vat dyes are made from indigo, anthraquinone and carbazole and are successfully used on cotton, linen, rayon, wool silk and sometimes nylon. These dyes also are used in the continuous piece goods dyeing process, sometimes called the pigment application process. In this method, the dyes are reduced after they have been introduced into the fabric.

Each vat dye has its own optimum temperature and specific proportions of alkali and reducing agents for vatting. In practice, however, it is practical to classify them into four groups, based on method of application:

Method 1: Dyes requiring relatively high alkali concentration and high vatting and dyeing temperatures.

Method 2: Dyes requiring moderate alkali concentrations, lower temperatures for reducing and dyeing, and some electrolyte to complete exhaustion.

Method 3: Dyes requiring low alkali concentration, low vatting and dyeing temperatures and large quantities of electrolyte.

Method 4: A special case for dyeing blacks requiring exceptionally high alkali concentration and temperature but no electrolyte.

In addition to the dyes, one or more of the following auxiliary chemicals may be necessary for satisfactory dyeing:

sodium hydroxide
sodium hydro sulfite
dispersing agents
hydrogen peroxide
acetic acid

sodium perborate
sodium chloride

2.4.11 Printing

Printing, like dyeing, is a process for applying color to fabric. However, the color application techniques are quite different. Instead of coloring the whole cloth as in dyeing, print color is applied only to specific areas of the cloth to achieve a planned design. Consequently, printing often is referred to as localized dyeing.

Most of the textiles wet-printed in the U.S. are printed by the roller machine method and a smaller proportion by the screen method. Highly advanced electronically-controlled spray printing techniques are beginning to emerge, especially in the printing of carpet.

Roller printing is accomplished by transferring the desired design onto copper rollers; applying print paste from reservoirs to rotating rollers that contact a main cylinder roller that transports the fabric; transferring the design to the fabric by contacting the rollers and fabric; and steaming, aging or performing other after-printing operations.

The design can be transferred to the rollers by hand engraving, photo engraving or chemical etching. The latter two methods are used most today. The copper rollers, as many as 16 per print machine, may have a circumference of from 35 to 91 cm 14 to 36 in.), and a length of from 117 to 152 cm (46 to 60 in.). They are hollow, and steel mandrils are pressed into the hollows to hold the rollers in position and to turn them at the desired speed. The rollers generally are coated with a thin layer of chromium to prevent damage to the engraving during handling. Each roller imprints one repeat of the design with color supplied from the color trough. As the roller spins, a doctor knife continuously scrapes the extraneous color back to the color trough. A different design and color can be transferred for each roller. Generally, only one side of the fabric is printed.

Final washing of the fabric removes excess print paste and leaves a uniformly smooth effect. This process, along with the cleanup of print paste mixing tanks, applicator equipment (troughs and rollers) and belts, contributes the pollutant loading associated with the printing process.

Screen printing differs from roller printing in that the print paste is transferred forcibly to the fabric through the openings in specially designed screens. The process can be manual, semiautomatic or completely automatic. Automatic screen printing can be either flat bed or rotary, while manual and semiautomatic screen printing are flat bed processes only.

21

Screens are made by manually (sketching or tracing) or photographically transferring the desired design. If the transfer is performed manually, the area outside the design is opaqued so that print paste will be retained. In the photographic transfer technique which is the method most widely used in current practice, the negative is used for the opaquing process, using a specially sensitized coating. The screens, which are largely made of synthetic materials today, are securely stretched over a wooden frame so they can be correctly positioned. A separate screen is made for each color in the design.

In manual screen printing, the fabric is stretched out on long tables, the screens representing the pattern laid on it according to the repeat pattern, and the selected print paste forced through the screen mesh onto the fabric by squeegee. The fabric is dried by placing it on a rack above the table, steamed to set the color, followed by other finishing treatments for fineness and texture.

The semi-automatic process is similar to the manual process except that the fabric travels and the screens representing the pattern are stationary. The handling of the screens and the application of the color still are performed manually.

Automatic flat bed screen printing is accomplished on a machine that electronically performs and controls each step of the operation. It is a continuous process in which the fabric moves along a table, the screens representing the design are automatically positioned and the color automatically is deposited and squeegeed through the screen onto the fabric. The fabric moves forward one frame between each application of color and as it leaves the last frame, it passes into a drying box, from which it emerges dry and ready for aging (curing).

Rotary screen printing combines some of the advantages of both roller printing and screen printing. Instead of flat screens, the color is transferred to the fabric through lightweight metal foil screens that resemble the cylinder rollers of the roller printing process. The desired design is transferred to the foil screens in much the same way as for the flat screens. The fabric moves continuously under the cylinder screens and print paste is forced, under pressure, from the inside of the screens through and onto the fabric. A separate screen is required for each color in the design.

Rotary screen printing is faster than flat bed printing and approaches the production speed of roller printing. The down time (out of production time) during pattern changeover is somewhat less than for roller printing. As with roller printing, wastewater is generated primarily from the final cleaning of the fabric, cleanup of applicator equipment and cleaning of belts.

Another type of printing that is in use today is sublistatic (heat transfer) printing. This method employs a prepared pattern paper from which a design can be transferred to nearly any fabric by a simple hot transfer or calendering operation. The main advantages of the sublistatic process are ease of application, clarity of reproduction, flexibility in design choice and a wide range of design sizes. After printing, no subsequent treatment such as washing or steaming is required and there is no print paste to clean from equipment. Consequently, the process does not generate wastewater.

The auxiliary chemicals used in printing each of the dye types are included in the lists provided in the discussion of dyeing. In addition, a thickener is used to give the print paste the desired viscosity for the method employed and the pattern desired. The thickeners commonly used are locust bean, guar, alginate, starch and combinations of these gums. Urea, thiourea and glycols also are used in many print formulations.

In printing with pigments, which do not react chemically with the fiber as do some dyes, the same general formula is used for all fiber types. The formula includes the pigment, resin, binder, latex, emulsifier, varsol (solvent), thickener and water.

2.4.12 Cleaning Operations

Cleaning equipment with chlorinated solvents is a common practice in the textile industry. Chlorinated solvents such as PERC, TCA and TCE are used to remove oil, wax, grease, and lubrication fluids form equipment. The solvents are applied as cold cleansing agents and they are popular because of their good solvency for organic materials and low heat of evaporation. They are nonflammable, noncorrosive, and relatively stable.

Solvent cleaning is a source of chlorinated solvent emissions and hazardous waste generation. The level of these releases depends on individual operations.

2.5 FINAL PRODUCTS

The textile mill products group in the U.S. includes 30 separate industries that manufacture approximately 90 classes of products. Throughout the 90 product classes, there are hundreds of individual products and the number is changing constantly as a result of ongoing research, development and marketing. Many of the industries and product classes do not include wet operations in their manufacturing processes and, consequently, are not of specific interest here.

A description of each major class (subcategory) follows.

2.5.1 Wool Stock and Top

Raw wool is very dirty and must be cleaned and prepared before it can be processed. A number of mills scour wool and make wool top as a final product and ship it to other facilities for further processing. A schematic of a typical wool scouring operation is presented in Exhibit 2-3. Raw wool is scoured after it has been sorted and blended. The scouring process has been described previously. Most mills in this segment practice countercurrent flow of wash water and recover grease from the scour waste. The scoured wool must be dried thoroughly to prevent rancidity. Dried wool may be shipped as a final product, combed to create wool top or finished in another portion of the mill.

2.5.2 Finished Wool Goods

Wool not only requires more preparation than other fibers, but also requires unique finishing operations. As a result, there are a number of mills in the industry devoted exclusively to finishing wool goods. A schematic of the typical wool finishing process is presented in Exhibit 2-4. Finished wool products include top, yarn, blankets and fabrics for apparel, upholstery, outerwear and numerous other uses. A single mill may manufacture any number of these products. Light scouring, dyeing and washing are employed regardless of whether top, yarn or fabric is being finished. In addition, carbonizing, bleaching, oiling, carding and spinning may be performed when finishing wool top. Carbonizing and bleaching also are performed at mills finishing wool fabric, as is fulling (felting) and final finishing. Knitting or slashing and weaving must be performed to produce wool fabric from yarn. These steps can occur at a greige mill, at a top finishing mill after spinning, at a yarn finishing mill after dyeing and washing, or at a fabric finishing mill prior to carbonizing or fulling.

2.5.3 Greige Goods and Adhesive Products

Greige goods are materials that are woven or knit, but not finished. A large number of mills perform the mechanical operations to produce greige goods and ship them to other mills for dyeing and finishing. The manufacture of woven greige goods is the only fabric construction process that results in the generation of process wastewater. A typical woven greige mill operation (Exhibit 2-5) consists of opening and picking the fiber, carding and spinning the fiber into yarn, applying size to the yarn and weaving the yarn into fabric on a loom. Usually, only a small quantity of wastewater is generated during slasher cleanup, although at the few mills where water jet weaving is employed, the wastewater discharge may be substantial.

Adhesive products are goods that have been created or modified because of operations such as bonding, laminating, coating or flocking. Backed carpet, tire cord fabric other coated fabrics, laminated fabric, and flocked fabrics are the principal products. A schematic of a typical

Exhibit 2-3
Typical Wool Scouring Process Flow Diagram

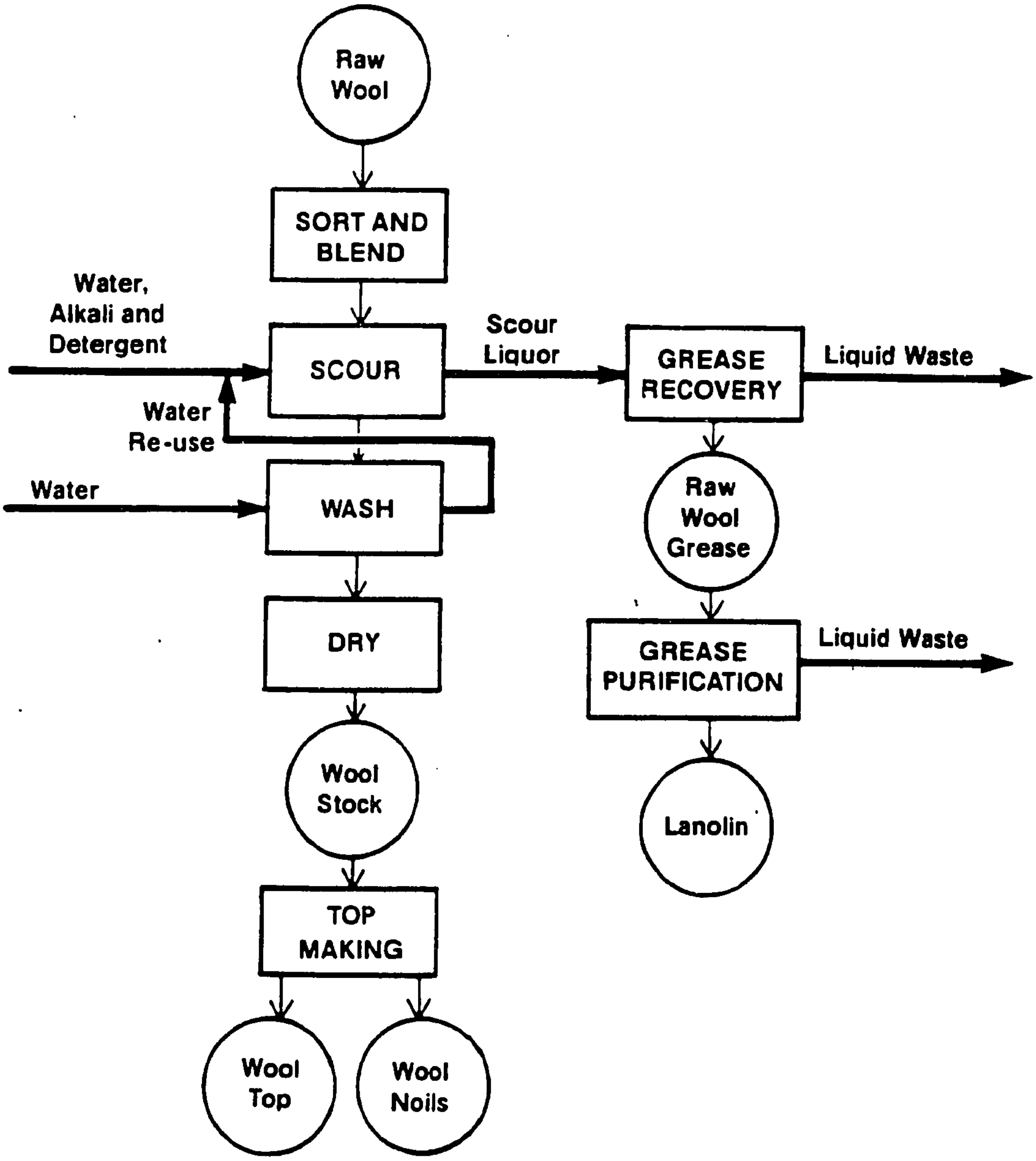
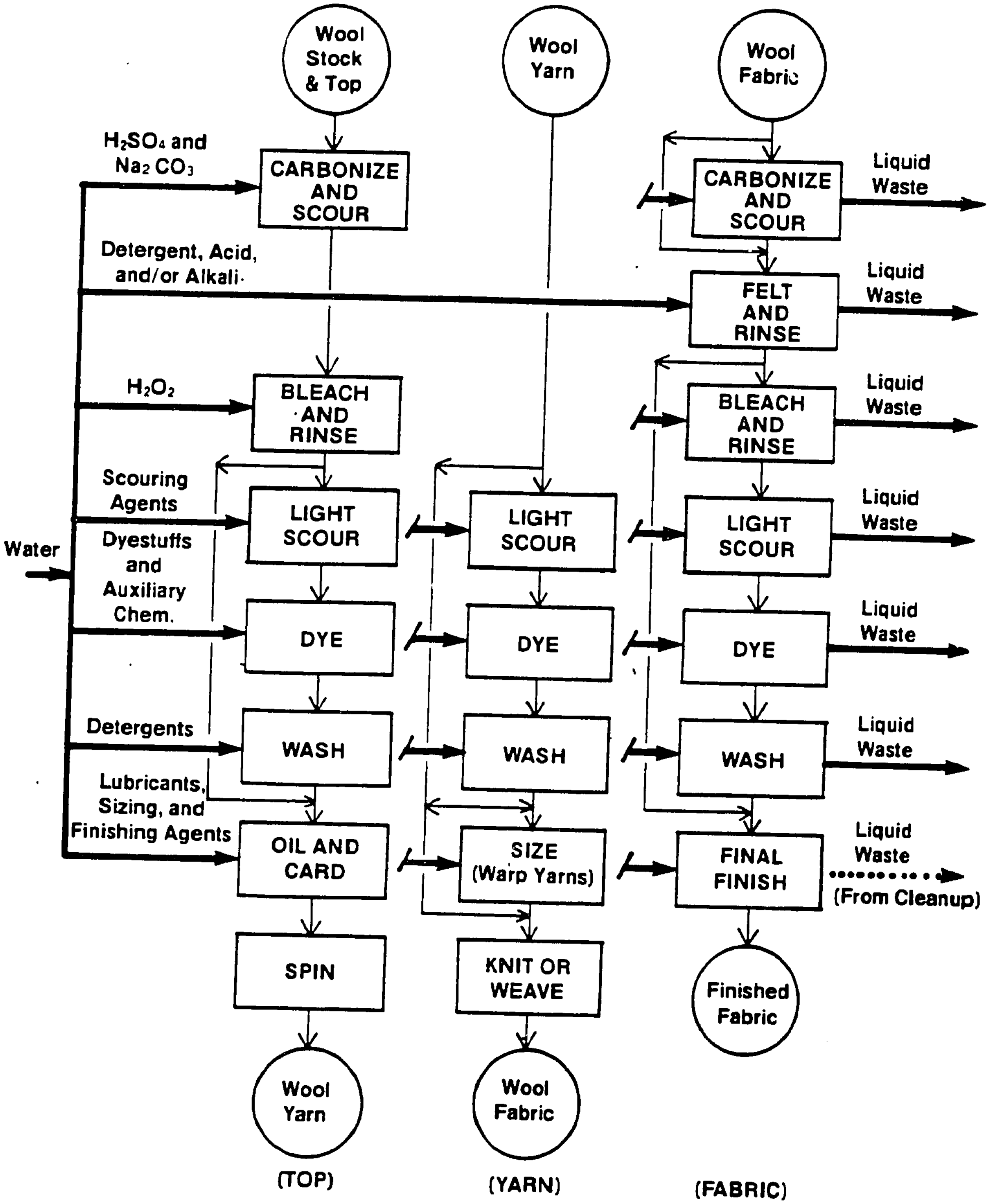
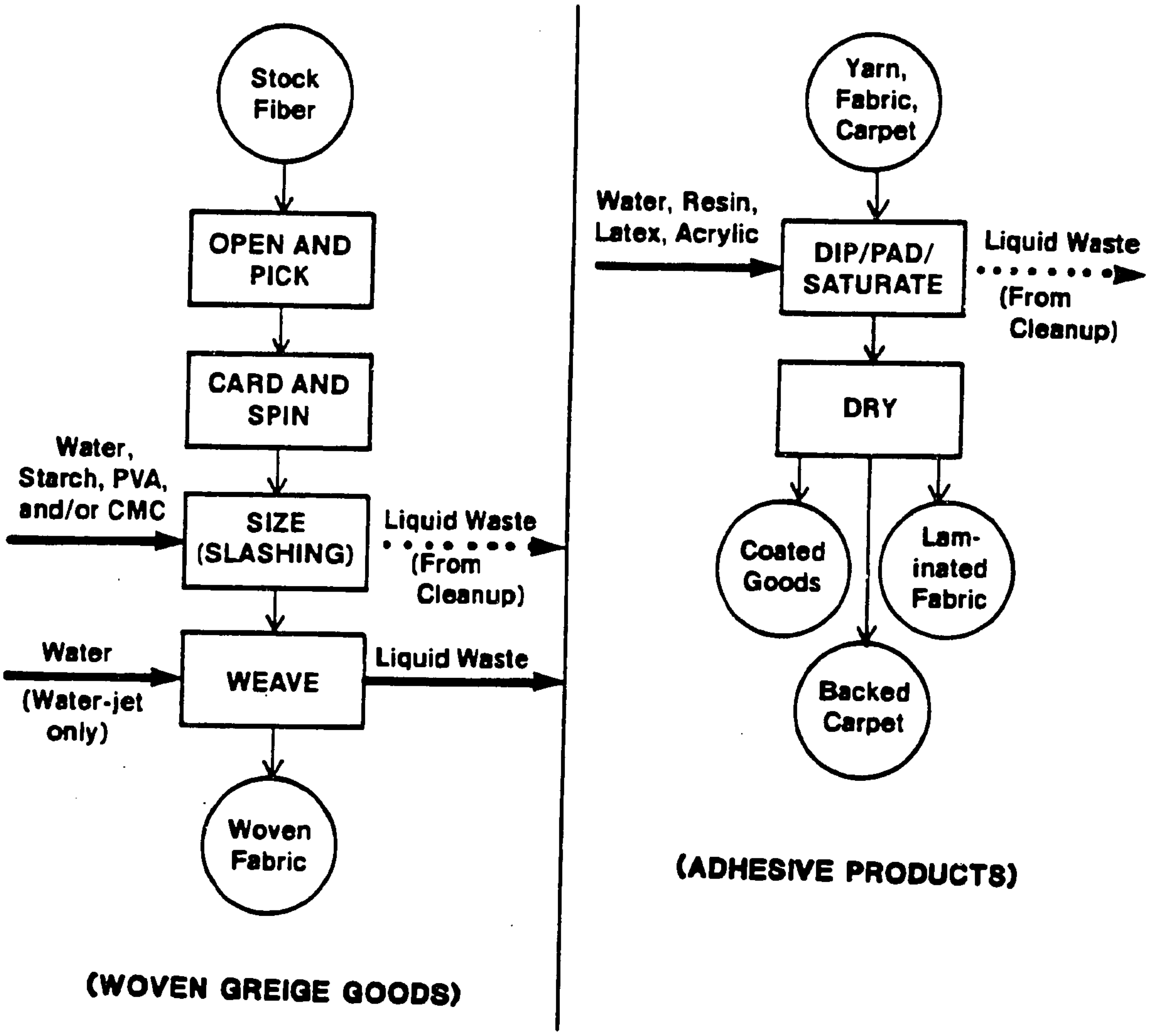


Exhibit 2-4
Typical Wool Finishing Process Flow Diagram



37

Exhibit 2-5
Typical Low Water Use Processing Process Flow Diagrams



adhesive operation is also presented in Exhibit 2-5. Application of adhesive and setting or drying are the main adhesive processes.

2.5.4 Finished Woven Goods

Finished woven fabric is a primary textile product that is used in countless applications. Sheeting, industrial fabrics, upholstery, towels and materials for numerous types of apparel are finished at those mills. A typical process flow diagram is presented in Exhibit 2-6. For cotton fabrics, typical processing consists of desizing to remove size applied to the yarn prior to weaving, scouring to remove natural and acquired impurities from the fabric, mercerizing to increase the luster, strength and dye affinity of cotton fabric, bleaching to whiten cloth and remove stains, dyeing and/or printing to impart desired colors and patterns to the fabric and final finishing to add other desired qualities and properties to the fabric. For synthetic fabrics, extensive desizing, mercerizing and bleaching are less common.

2.5.5 Finished Knit Goods

Finished knit goods include fabrics and hosiery. Principal fabric products are underwear, numerous types of outerwear, various types of household and industrial items, circular knits and warp knits. Hosiery products include both conventional footwear, ladies nylon hose and pantyhose. Typical process flow diagrams for knit fabric processing and hosiery processing are presented in Exhibit 2-7. Knit fabric finishing is similar to the finishing required for woven goods, except that desizing and mercerizing are not necessary. Hosiery finishing usually is simpler because the cleaning and dyeing processes often are combined and can be less extensive.

2.5.6 Finished Carpet

Carpet manufacturing is an important and distinct segment of the textile industry. Most carpet mills are integrated operations that tuft, finish and back carpet at the same location. Finishing operations may include scouring, bleaching, dyeing, printing and application of functional finishing agents. A typical process flow diagram is presented in Exhibit 2-8.

2.5.7 Finished Stock and Yarn

Many of the products previously noted often are manufactured from finished yarn. Stock also is used in the manufacture of products already noted. Both yarn and thread are used outside the industry and as such are sold as final products. A schematic of typical yarn and stock finishing operations is provided in Exhibit 2-9. Yarn finishing and stock finishing basically involve the same processes except that mercerizing is not performed on stock.

Exhibit 2-6
Typical Woven Fabric Finishing Process Flow Diagram

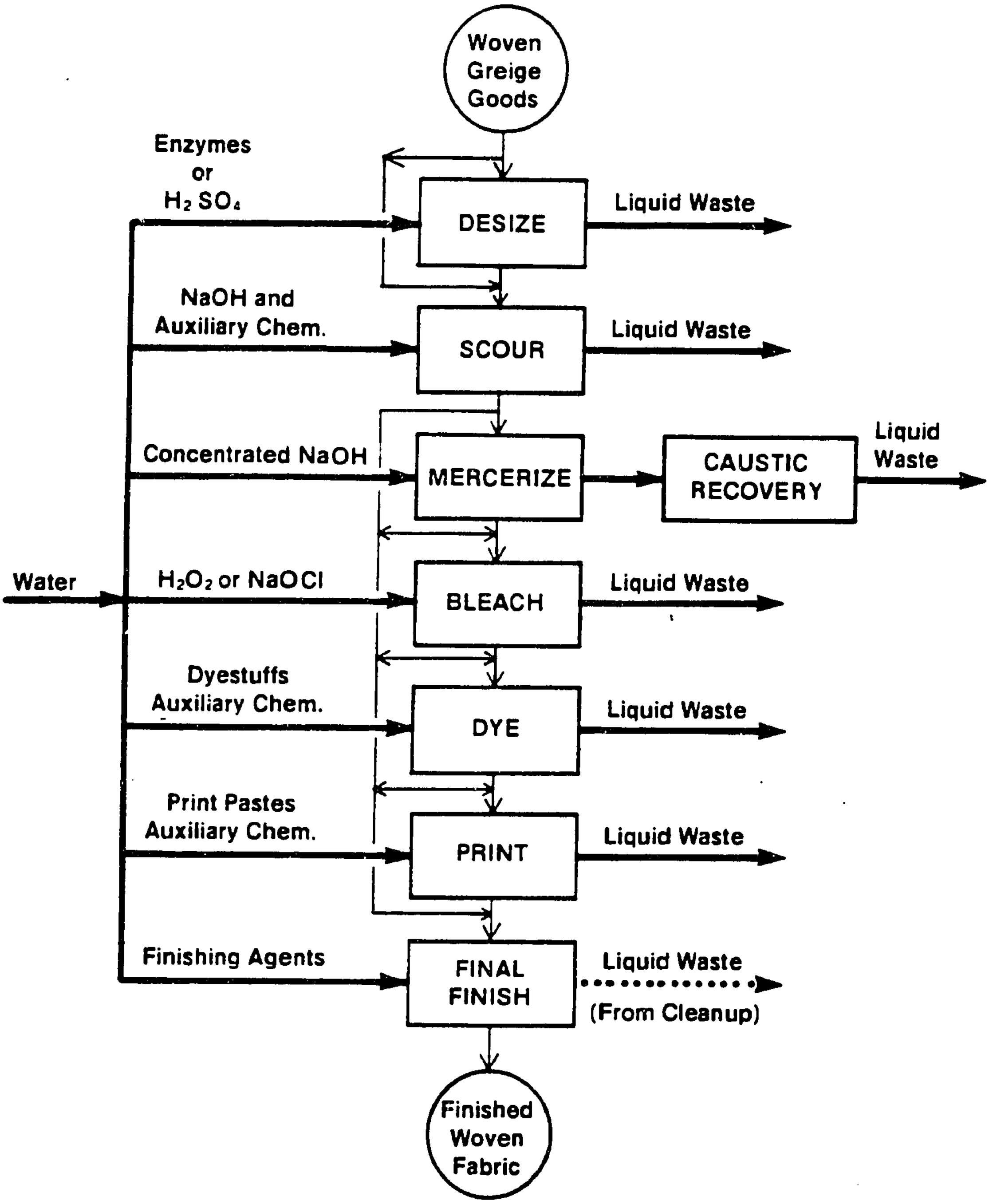
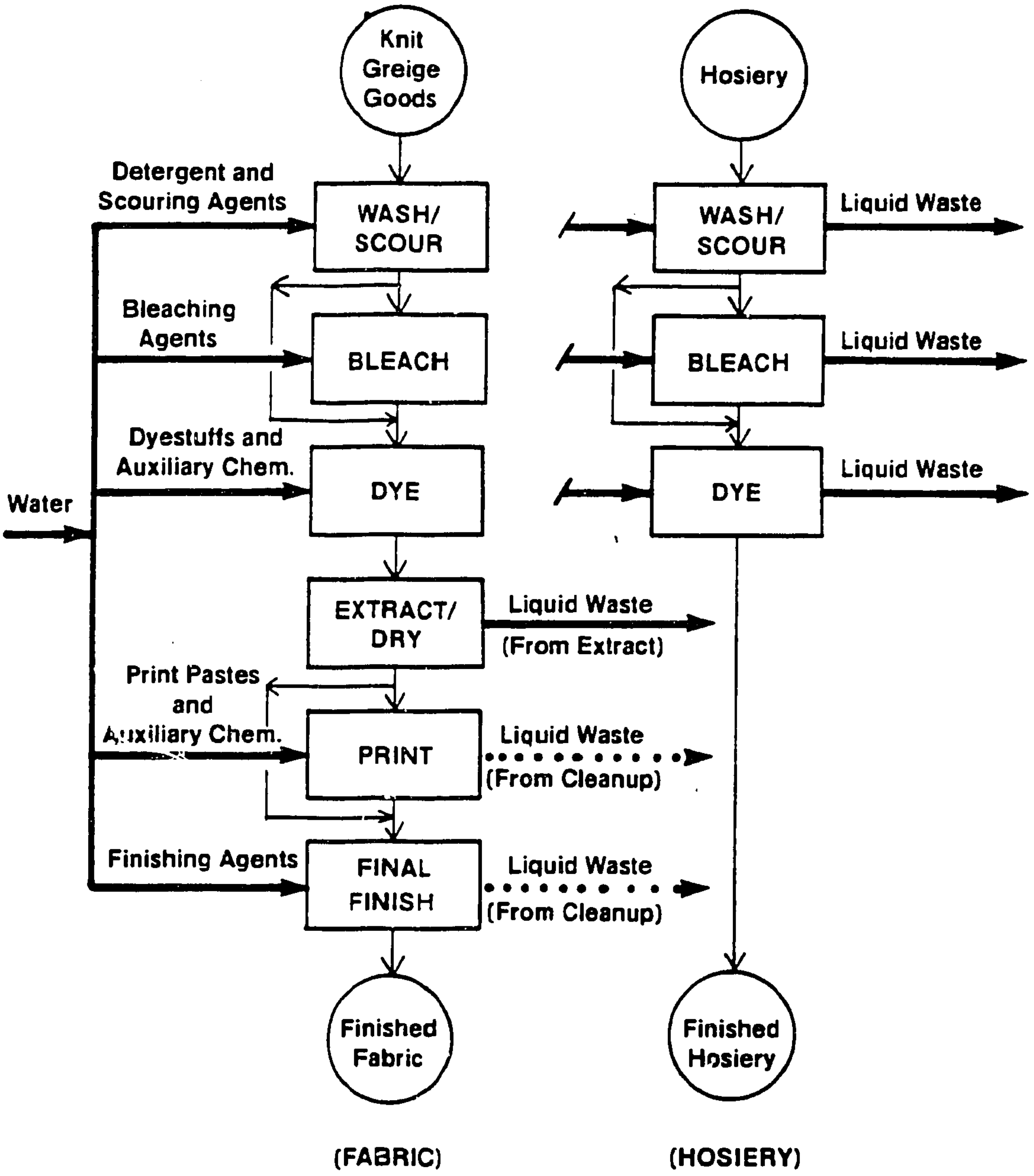
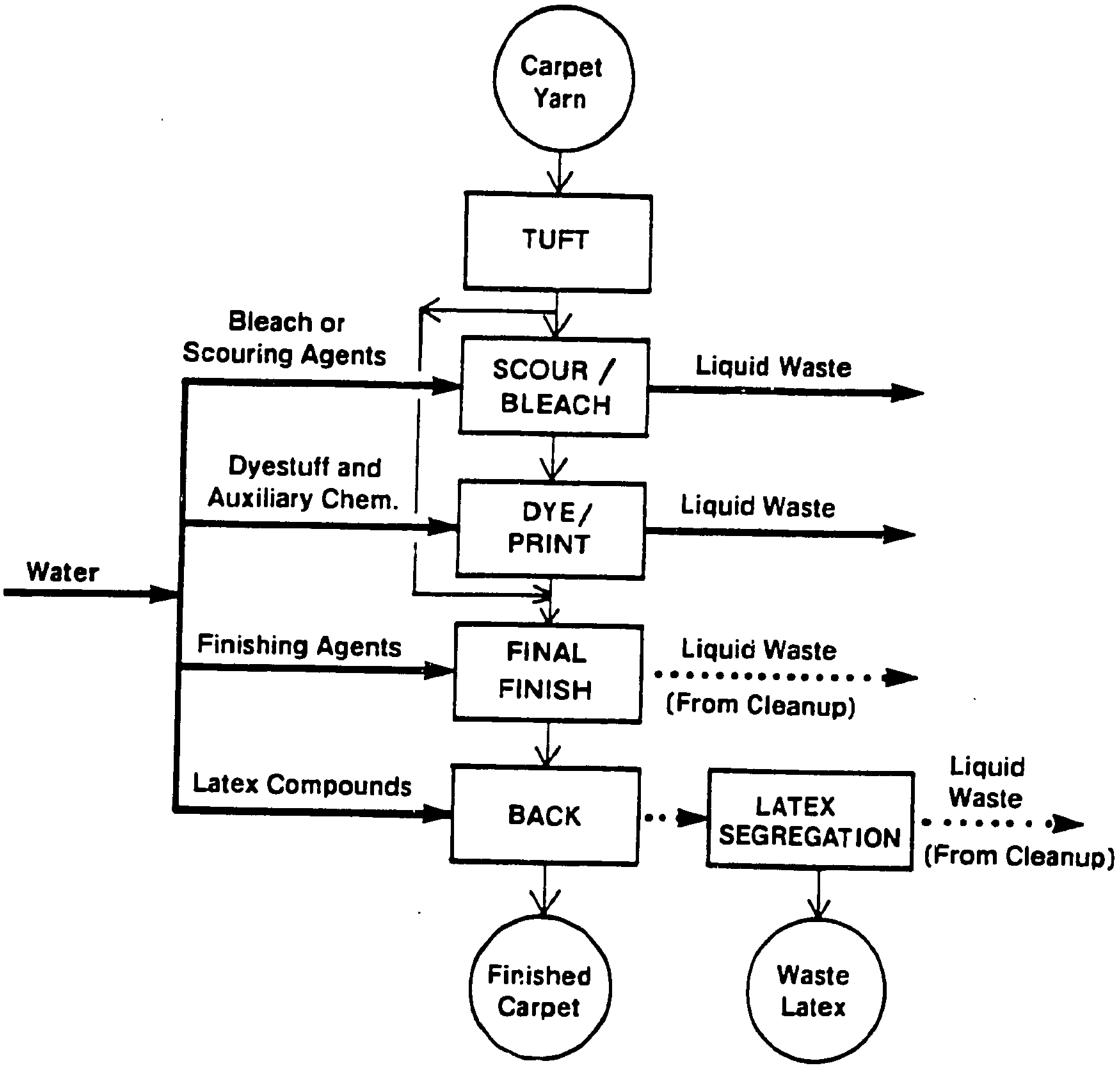


Exhibit 2-7
Typical Knit Fabric Finishing Process Flow Diagram



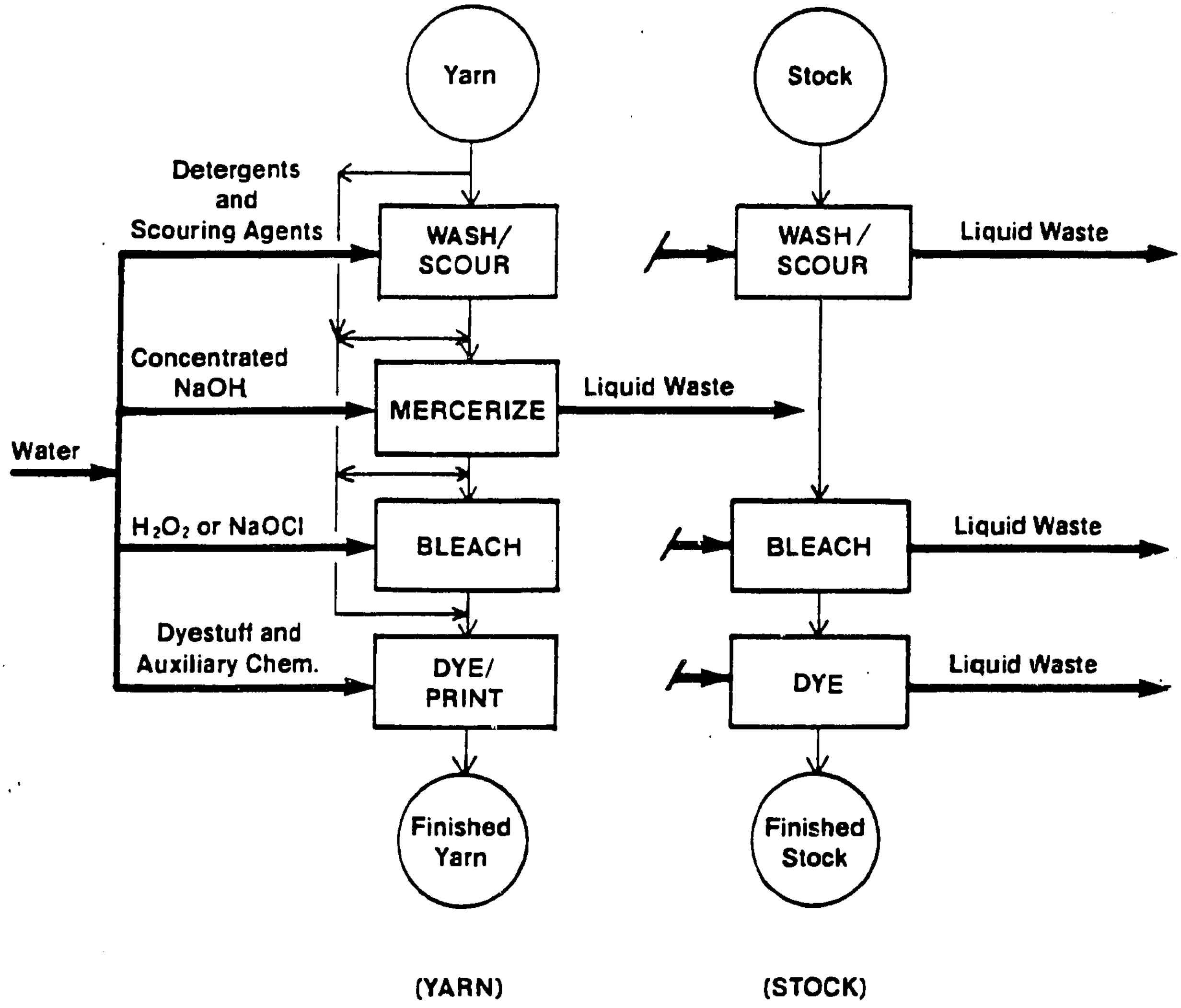
36

Exhibit 2-8
Typical Carpet Finishing Process Flow Diagram



37

Exhibit 2-9
Typical Stock and Yarn Finishing Process Flow Diagram



38

2.5.8 Nonwoven Goods

Nonwoven manufacturing is a relatively new and rapidly growing segment of the textile industry. Typical products include filter media, diapers, interliners, padding, surgical gowns, absorbent wipes and other disposable products, as well as fabrics for other uses. A schematic of a typical nonwoven manufacturing operation is presented in Exhibit 2-10. Web formation is a dry operation unless the wet-lay process is employed. In the latter case, a portion of the water used to transport the fibers and form the web often is discharged.

2.5.9 Felted Fabric

Although felted fabrics comprise a relatively small segment of the textile industry, they are used in a variety of applications. In addition to woven papermakers' felt, there are pressed felts and punched or needleloom felts. Typical products include polishing cloth, insulating fabric, lining, trimming, acoustical fabric, automotive padding, felt mats and felt apparel fabric. A typical felted fabric processing flow diagram is presented in Exhibit 2-11. Rinsing following fulling and dyeing (if employed) is responsible for the rather high water use of this segment.

Exhibit 2-10
Typical Nonwoven Manufacturing Process Flow Diagram

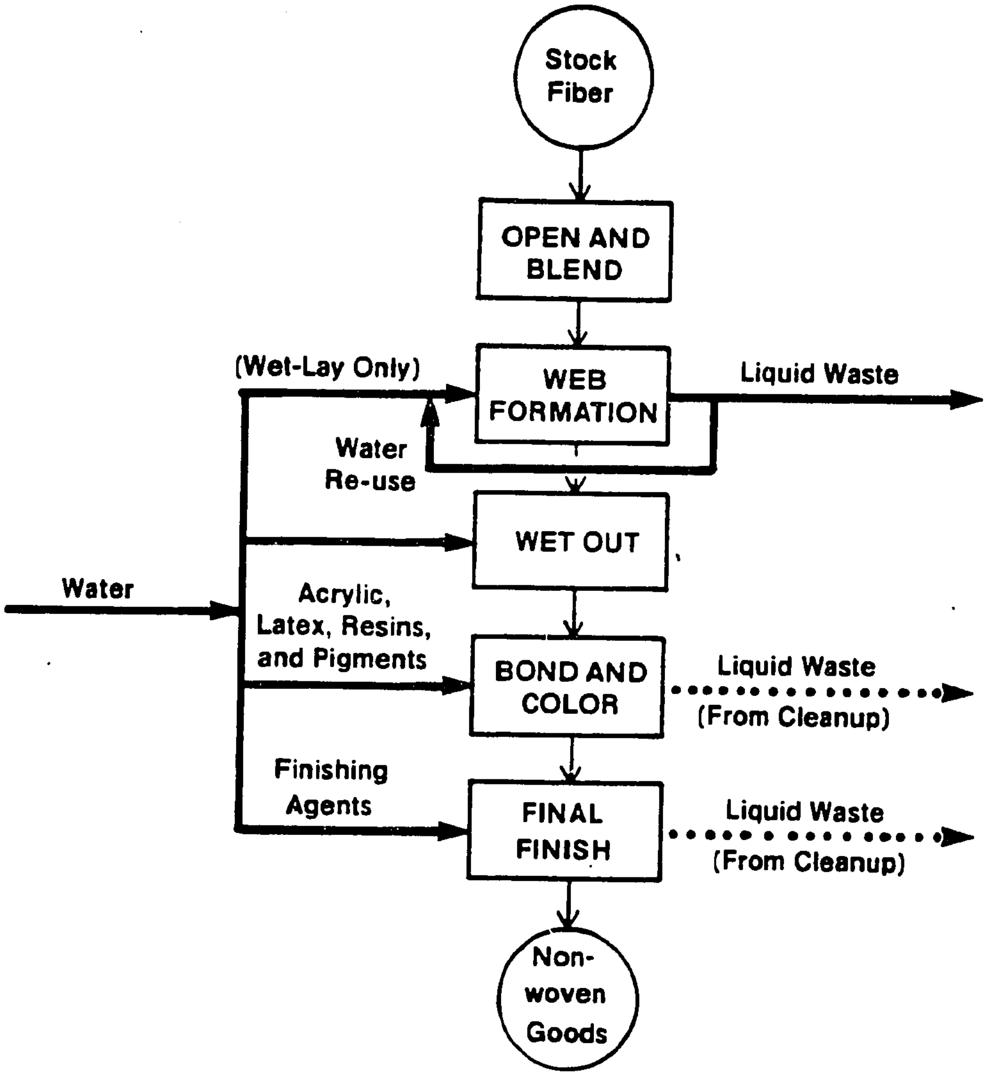
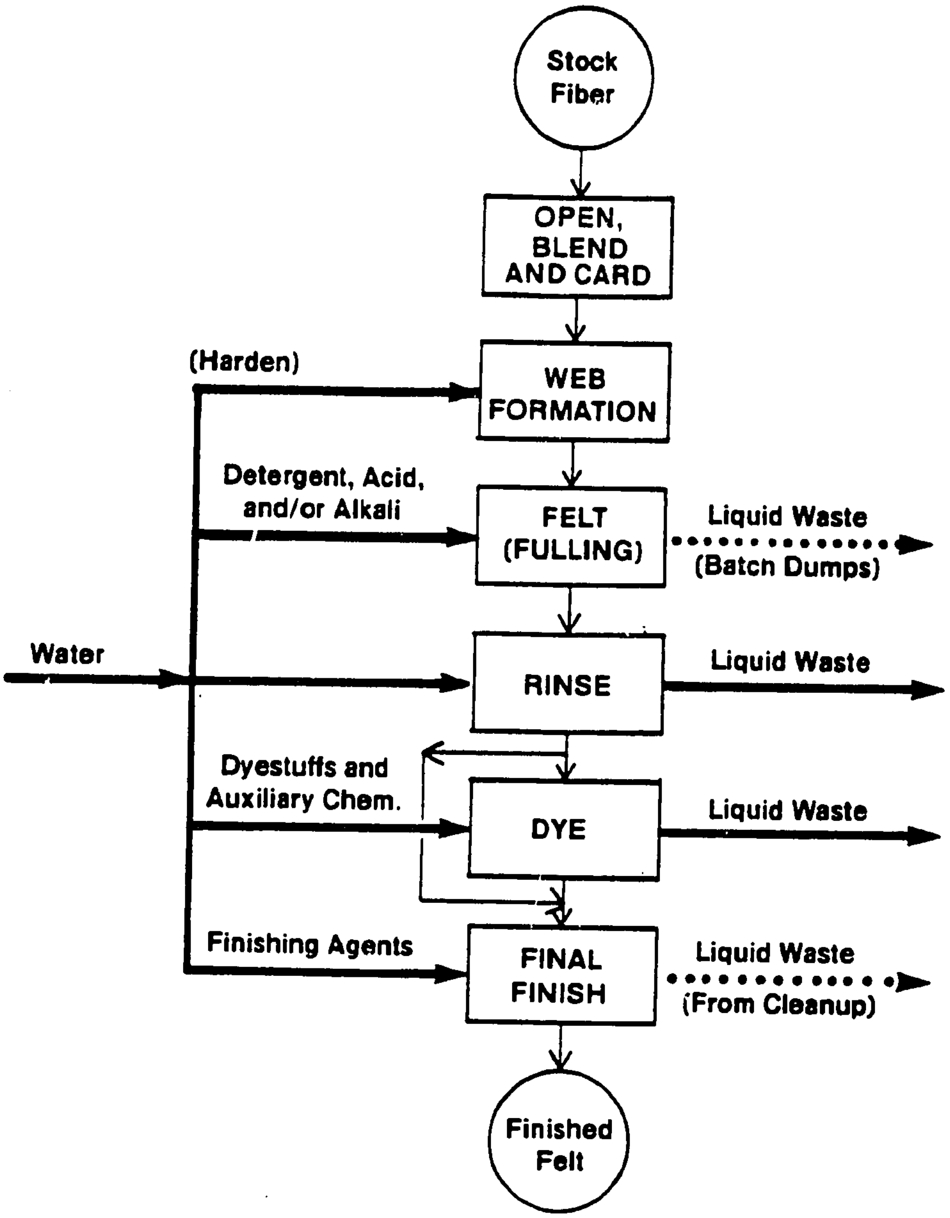


Exhibit 2-11
Typical Felted Fabric Processing Process Flow Diagram



CHAPTER 3
SOURCES OF WASTE[1]

It is important for each source of waste to be carefully identified for a textile processing operation. This can be done by 1) inventory control and knowledge of potential pollutants in purchased products or 2) process analysis.

This section will concentrate on the identification of pollutant sources in textile processing. Specific types of pollutants that will be considered in detail are:

- BOD
- Toxicity
- Acidity/Alkalinity/pH
- Metals
- Air Emissions.

3.1 SOURCES OF BOD

In order to identify processes and their contributions to BODs in waste streams, each textile wet processing step will be listed with appropriate general comments concerning the potential BOD contributions (see Exhibit 3.1).

BOD is an indirect measure of the amount of organic material present in water which can be biologically degraded (by microorganisms). Since dissolved oxygen is depleted in the process of degrading organic material, the amount of organic material can be expressed in terms of the amount of oxygen required. As oxygen is utilized in a body of water receiving organic waste, water conditions can become septic resulting in water quality and public health problems.

---

[1] This chapter is derived from the following documents:

North Carolina Department of Environment, Health, and Natural Resources, *Identification and Reduction of Pollution Sources in Textile Wet Processing*, by Brent Smith, Department of Textile Chemistry, North Carolina State University: Pollution Prevention Pays Program, 1986.

Source Reduction Research Partnership, *Textiles Manufacture - Source Reduction of Chlorinated Solvents,* prepared for California Department of Toxic Substances Control and the USEPA Office of Research and Development Risk Reduction Engineering Laboratory, June 1991.

42

The BOD values of products given in tables represent data that have been previously published. Extensive lists of BOD data of textile chemical specialties are circulated privately, but cannot be published because they are proprietary.

Certain chemical manufacturers will share the data on their products freely while others will not. One way for a mill to overcome this problem, if it arises, is to insist that BOD, COD, and other data be presented, along with other essential data (e.g., Material Safety Data Sheets or MSDS) as part of product evaluation prescreening procedures as discussed in Section 3.4.

3.1.1 Preparation

Preparation processes include the following typical BOD contribution.

Exhibit 3-1
BOD Contributions of Various Textile Processes

Process	**#BOD per 100# fabric**
Singe (woven only)	None
Desize (woven only)	
Enzyme/starch	67
Starch/CMC mix	20
PVOH or CMC only	~ 0
Scouring	45-50
Bleaching	
Peroxide	3-4
Hypochlorite	8
Mercerizing	
(no caustic recovery)	15
(with caustic recovery)	6
Heatsetting (synthetic only)	~ 0

3.1.1.1 Desizing

Desizing of woven fabrics is the first major wet processing step. There are many types of sizing materials available, and most commercial sizes are mixtures.

Starch sizes will generally have BODs of 500,000 to 600,000 ppm; alginates and modified starches, 100,000 to 500,000 ppm; and synthetic sizes (PVOH, CMC, PVAc), about 10,000 to 30,000. In addition, starches are generally removed with enzymes which themselves have BODs typically over 10,000 ppm. The removal of CMC, PVOH, and PVAc and other synthetic sizes is usually accomplished with hot water and perhaps alkali so that the removal system itself does not normally contribute to BOD load. Furthermore, synthetic sizes can generally be recovered from waste streams. Thus a change from starch to synthetic sizes can give BOD reduction from this major source of over 90%. In a typical operation, this would be about 50% of the total BOD load from preparation for woven fabrics (but not knits).

Other factors to consider are auxiliary components of size mixtures that are commonly used in commerce. Components of commercial mized size formulations are summarized in Exhibit 3-2. Other commonly used components and their respective BOD concentrations are provided in Exhibit 3-3.

Exhibit 3-2
Components of Commercial Mixed Size Formulations

Component	% of Total Size Mix Solids
Size (starch, CMC, PVOH, PVAc, etc.)	85-90%
Humectant (urea, diethylene glycol, etc.)	2-5%
Lubricant (wax or oil)	2-5%
Antistat	0.5%
Biocide	varies
Glycerine (improves adhesion for spun yarns)	2.0%
Wetter (improves penetration for filament)	

Exhibit 3-3
BOD of Other Size Components

Materials	BOD (ppm)
Urea	90,000
Glycerine	640,000
Waxes	100,000 to 1,500,000
Oils	100,000 to 1,500,000
Antistat	varies widely
Bactericide	test fails
Wetter/penetrant	varies widely
Diethylene glycol	60,000
Wetters	varies widely

3.1.1.2 Scouring

Scouring processes are for removal of oils, waxes and other impurities. This is generally accomplished by either emulsification of synthetic oils and waxes, or by saponification of naturally occurring impurities (triglycerides). Typically, scouring wastes contribute a large portion but less than 50% of BOD loads in waste streams from preparation processes.

Synthetic oils and waxes include winding emulsions, paraffin wax, knitting oil, coning oil, and other lubricants. These materials have significant BOD themselves, and the emulsifiers used to remove and suspend them in preparation also contribute.

In addition, surfactant BODs vary widely, the highest being natural soaps which are saponification products of triglycerides (glycerol esters of naturally occurring long-chain fatty acids) such as lauric and oleic acid. The fatty acids and/or their salts are sometimes used as scouring agents in alkaline medium. These typically have BODs over 1 million ppm. Synthetic detergents have lower BODs.

However, the use of lower BOD products per se is not always desirable. For example, branched alcohol ethyoxylates are known to be less degradable, therefore, have lower 5-day BOD than linear alcohol ethoxylates. In a typical activated sludge waste treatment system, therefore, these branched materials will not be degraded to the same degree as their linear counterparts: They will pass through to a greater extent and therefore increase the aquatic toxicity of treated effluent. Toxic components of effluents are of great concern currently. These materials can also affect treatment system performance adversely.

Exhibit 3-3
BOD of Other Size Components

Materials	BOD (ppm)
Urea	90,000
Glycerine	640,000
Waxes	100,000 to 1,500,000
Oils	100,000 to 1,500,000
Antistat	varies widely
Bactericide	test fails
Wetter/penetrant	varies widely
Diethylene glycol	60,000
Wetters	varies widely

3.1.1.2 Scouring

Scouring processes are for removal of oils, waxes and other impurities. This is generally accomplished by either emulsification of synthetic oils and waxes, or by saponification of naturally occurring impurities (triglycerides). Typically, scouring wastes contribute a large portion but less than 50% of BOD loads in waste streams from preparation processes.

Synthetic oils and waxes include winding emulsions, paraffin wax, knitting oil, coning oil, and other lubricants. These materials have significant BOD themselves, and the emulsifiers used to remove and suspend them in preparation also contribute.

In addition, surfactant BODs vary widely, the highest being natural soaps which are saponification products of triglycerides (glycerol esters of naturally occurring long-chain fatty acids) such as lauric and oleic acid. The fatty acids and/or their salts are sometimes used as scouring agents in alkaline medium. These typically have BODs over 1 million ppm. Synthetic detergents have lower BODs.

However, the use of lower BOD products per se is not always desirable. For example, branched alcohol ethyoxylates are known to be less degradable, therefore, have lower 5-day BOD than linear alcohol ethoxylates. In a typical activated sludge waste treatment system, therefore, these branched materials will not be degraded to the same degree as their linear counterparts: They will pass through to a greater extent and therefore increase the aquatic toxicity of treated effluent. Toxic components of effluents are of great concern currently. These materials can also affect treatment system performance adversely.

3.1.1.3 Bleaching (BOD)

The BOD contribution from continuous bleaching operations is fairly low, less than 5% of the total textile mill BOD, typically. In addition, many synthetic fibers and blends require little or no bleaching compared with fabrics and yarns of pure cotton or wool. Thus, current commercial practice is such that the BOD from bleaching operations is not a critical factor in overall BOD production. However, wetting agents and other auxiliaries are sometimes used which can contribute to BOD load and toxicity. Also, some mills use a modified procedure in which scour and bleach may be combined. Thus, the overall impact of process control and source reduction in bleaching is site-specific.

3.1.1.4 Other Preparation Processes (BOD)

Other preparation processes include heat setting (synthetics), and mercerizing (cotton). These preparation processes as well as bleaching contribute relatively little to waste stream BODs as compared to desizing and scouring.

3.1.2 Dyeing

Dyeing processes vary greatly in the amount and type of wastes produced. Many details of exhaust dyeing processes are discussed in Chapter 5 of this document on dyebath reuse. Continuous dyeing methods including pad batch dyeing generally use much lower quantities of chemicals and water than exhaust methods.

3.1.2.1 Continuous Dyeing

The primary source of BOD from continuous dyeing is the soap-off chemicals (surfactants) and the dyeing auxiliaries used in the pad bath, which may wash off. Also, reducing agents sometimes give high BOD values. Because of the continuous nature of these processes, the waste streams are easily segregated for heat recovery and other management strategies. Since the waste from continuous dyeing is usually mainly wash water, the chemical content is usually relatively low compared to desizing or scouring wastes or spent batch dye liquors. Thus, BOD source reduction in continuous dyeing processes does not hold the potential for improvements that batch dyeing does.

3.1.2.2 Batch Dyeing

Problems with spent dye liquors from batch dyeing are much more difficult to handle because:

1) waste streams are usually dumped into common pits or trenches, making segregation difficult

47

2) batch waste dumps occur at discrete intervals, timing is not predictable, and any restrictions on timing cause severe scheduling problems

3) the nature of the processes and chemicals used vary greatly.

There has been interest in dye waste reuse; however, only a few direct reuse situations have been commercially adapted. Another example of reuse of dyehouse batch processing waste is the reuse of final rinse/softener baths (especially for hosiery) for prescouring the next batch of substrate, especially synthetics. Presumably, after softener is exhausted onto the substrate, its emulsifier system is still available for scouring fiber finish and knitting oils from the next batch. Energy savings also occur because the exhausted softener bath is usually hot. Exhibit 3-4 summarizes waste characteristics (BOD) for each class of dye that is commonly applied by exhaust methods.

3.1.3 Finishing

Finishing is typically a continuous process that produces little or no waste water except perhaps noncontact cooling water and some afterwashing waste (rarely). Occasionally there is condensate from steam heated equipment also, but the quantity is quite small compared to dye and preparation waste. Another source of potentially significant waste is dumping of unused finish mixes containing resins, catylsts, wetters, softeners, builders, and other materials. Source reductions for finishing can be accomplished by adding and reusing finish mixes rather than dumping whenever possible.

A few types of finishes are applied by exhaust methods. These are generally done after, or as part of, the dyeing process and include softeners, lubricants, fixatives, and other special finishes (flame retardants, soil release, anti-bacterial, etc.).

In general, wastes from these are difficult to control, and continuous processes should be used if possible to avoid waste water loads associated with these chemicals. Sometimes these wastes can be reused.

Exhibit 3-4
BOD of Dyeing Assistants (ppm)

Class	Fiber	Machines	Chemicals	BOD Contribution to Waste
Acid	Wool Nylon	Stock Skein Package Jig Beck Jet Beam	Surfactant Leveler Retarder Acid Dye Lubricant Salt	Moderate (varies) Varies (may exhaust) Low Low Varies (may exhaust) Nil
Basic	Acrylic Other polymers	Stock Package Beck Jet Beam	Surfactant Leveler Retarder Acid Dye Lubricant Salt Carrier	Moderate (varies) Varies (may exhaust) Varies Low Low Varies (may exhaust) Nil Varies (may be high)
Direct	Cellulose	Stock Package Jet Beck	Alkali (weak) Surfactant Retarder/Leveler Salt Lubricant Fixative Dye	Nil Varies (moderate) Varies (moderate) Nil Varies (may exhaust) Low (exhausts) Low
Disperse	Synthetic	Stock Package Beck Jet Beam	Acid (weak) Dispersant Dye Carrier Lubricant Reductive/afterscoure	Low High High (dispersant) High (varies) Varies (may exhaust Moderate to high
Fiber Reactive	Cellulose (wool)	Stock Jig Jet Beam Beck Skein	Alkali (strong) Salt Dye Dye Lubricant Soap-off	Nil Nil Nil Nil Varies (may exhaust) Moderate (varies)
Naphthol Sulfur Vat	Cellulose	Any ... (total production amount by exhaust is relatively low in NC)	Reducers, oxidants Dye Lubricant Buffer	Varies greatly

3.2 SOURCES OF TOXIC COMPOUNDS

The main components of wastewater include natural impurities in natural fibers and process chemicals added to treat fibers, yarns or fabrics. Textile processing plants use a wide variety of dyes and other chemicals, including acids, bases, salts, wetting agents, dyes, and other auxiliary finishes. Many of these are not retained in the final textile product but are discarded after a specific use. Combined textile plant effluent may, therefore, contain any or all of these compounds.

Many of these chemicals agents used in the textile industry are considered to be toxic and hazardous. The release of these substances to the environment may cause serious damage to the health and welfare of an exposed community or the affected ecosystem. These materials can create serious health hazards and diseases of a chronic nature. Surface water, groundwater, soils and air can all be contaminated by hazardous and toxic substances.

One of the primary environmental concerns now under study is discharge of toxic materials from point sources. Acute bioassay toxicity tests on textile mill effluents have shown varying degrees of aquatic toxicity. Many mill treated wastes show low toxicity in several tests, while others have shown high aquatic toxicity even in relatively low concentrations.

The exact identity of these toxics is not known nor is the identity of precursors of water borne toxics in textile processing. This subject is currently under study. In spite of the lack of specific information, studies of textile wastes and knowledge of the nature of textile chemicals, dyes, and processes allows for certain generalities.

Types of materials that may be expected to predominate in toxic textile wastewaters include:

- metals
- nondegradable surfactants
- toxic organic materials such as phenols, aromatic solvents methylene, chloride, perchloroethylene, and oxalic acid, to name a few.

3.2.1 Metals

Data published by the American Dyestuff Manufacturers Institute show that metals can be expected to be present in varying amounts in different dye classes. This is shown in Exhibit 3-5. Of course, individual members of each dye class vary widely in metal content.

Exhibit 3-5
Average Metal Content of Selected Dyes (ppm)

	Dye Class					
Metal	**Acid**	**Basic**	**Direct**	**Disperse**	**Fiber Reactive**	**Vat**
Arsenic	< 1	< 1	< 1	< 1	1.4	< 1
Cadmium	< 1	< 1	< 1	< 1	< 1	< 1
Chromium	9	2.5	3.0	3.0	24	83
Cobalt	3.2	< 1	< 1	< 1	< 1	< 1
Copper	79	33	35	45	71	110
Lead	37	6	28	37	52	6
Mercury	< 1	0.5	0.5	< 1	0.5	1.0
Zinc	< 13	32	8	3	4	4

A survey of dyes, performed in the mid 1970s, showed that the primary source of copper in wet processing waste from a major North Carolina mill was from dyestuffs. A check of each of the dyestuff showed that approximately 95% of the copper in the effluent originated from 13 dyestuffs which were manufactured with high copper contents:

Each of these dyes contained copper as an integral part of the molecular structure or its chromophore; therefore, most of the metal will exhaust onto the fabric with the dye. However, direct dyes typically remain 5% to 15% unexhausted in spent dye liquors. Thus some metal is discharged as waste. This particular mill did not use vat or fiber reactive classes for exhaust dyeing. Other metal sources that were specifically identified in this mill and which are typically present in wet processing operations were:

- Oxidizers for vat and sulfur dyes (chromium)
- Copper sulfate aftertreatment for direct dyes
- Metal catalyst used for curing resins (zinc, aluminum)
- Flame retardant, soil release, and water repellant finishes
- Greige goods
- Dye stripping agents such as permanganate, zinc sulfoxylate-formaldehyde, and dichromate

Two of these (oxidizers and aftertreatments) are directly related to dye application and are sometimes used to insure complete fixation and/or entrapment of the dye within the fiber. An example of this is the use of copper sulfate to aftertreat direct dyes, rarely practiced now in favor of the use of organic resinous fixatives. These resinous fixatives have higher nitrogen content and BOD, but have no copper content. An alternative procedure that avoids heavy metals and BOD both is to use epsom salts as an antimigrant until the fixative can be applied from a continuous resin finish formulation.

Also, certain dye classes require oxidation and/or reduction during the application and fixing of the dye. These dyes (particularly vats and sulfurs) were formerly oxidized with dichromate, but are now almost universally oxidized with other materials such as iodate, bromate, peroxide, etc.

Finally, repair procedures for many classes of dye can involve the use of metals and/or other toxic materials. One type is the zinc sulfoxylate-formaldehye type of dye stripping agent used on some classes of dyes. This type of repair procedure can contribute to zinc content of waste streams. Another common type of stripping procedure for resin finishes is oxalic acid. This material is known to be toxic. A stripping procedure involving phosphoric acid and urea is equally effective for most resin finishes and with much lower toxicity. These stripping procedures are for repair of defective fabric, but one source of toxic stripping agents that is sometimes overlooked is the machine cleaners used for dyeing machines, pad rolls, etc. These processes frequently are not controlled to the same extent as the dyeing processes, and the machine cleaner specialty chemicals frequently contain toxic solvents.

Another source of toxics that sometimes is overlooked is maintenance chemicals. The typical textile mill usually has some sort of approval procedure and quality control for raw materials used in processing, but sometimes maintenance chemicals escape approval because they do not directly affect the mill's direct cost and quality control, and because they are purchased and used less frequently than process chemicals. The control and evaluation of these materials should not be overlooked. Typical contents include methylene chloride, perchloroethylene, and other highly toxic materials.

Other types of nonprocess chemicals that have been known to contribute to toxicity of waste waters include biocides and herbicides. Biocides are frequently used in cooling towers and nonprocess water purification and processing. Biocides also are used in certain applications such as finishes for hosiery, tents, awnings and tarpaulins. Herbicides are used to control grass, weeds and other vegetation near bulk storage tanks, such as areas within a spill control berm, especially tanks of flammable materials such as natural gas, LP gas, fuel oil, and varsol.

3.2.2 Surfactants

Another group of materials that frequently contributes to textile mills' aquatic toxicity problems includes surfactants, detergents, emulsifiers, and dispersants. These are universally used in textile wet processing. The EPA development document for textile effluent guidelines clearly states substitution must be made carefully to avoid introducing nondegradable detergents (which will contribute to aquatic toxicity) for the purpose of lowering BOD. This advice has been frequently ignored in practice, primarily because surfactants are usually proprietary mixtures and the degradability data are not known to the mill.

3.2.3 Chlorinated Solvent Releases

There are three major chlorinated solvent loss mechanisms in the textile industry. The first--emissions to the atmosphere--are process emissions. The second loss mechanism is waste generation. The third is the water releases. Each of these releases are discussed in more detail below.

3.2.3.1 Atmospheric Releases. Although the solvent equipment used for scouring may be equipped with vapor control and totally enclosed, some solvent may still escape such processes. Causes of emission include carry out of the solvent on fabric, loss of solvent form equipment due to diffusion, filling/draining losses, wastewater losses, solvent recovery still losses, storage tank vent losses, and fugitive equipment leaks from pipes, valves, or pumps. the level of these emissions depends on the type, design, and size of the equipment, the number of hours of operation, and the operating techniques.

3.2.3.2 Hazardous Waste. Chlorinated solvents are used in the textile industry in the scouring operation as degreasing agents and as dye carriers. Chlorinated solvents become hazardous waste after use in these operations.

The solvents used as dye carriers contain various dyestuffs which are complex organic compounds that are refractory (nonbiodegardable) and hazardous. Dyestuffs contain heavy metals, such as chromium, copper and zinc, and organics. Only about 50 weight percent of commercial dye is dyestuff. The remainder is usually nonhazardous filler (such as sugar) and surfactant. The dyestuff ends up in the waste solvent which may be recovered on-site or sent for off-site recycling. Some spent dyes may be released to the water treatment systems.

The scouring hazardous waste includes contaminated liquid solvent, bottoms from solvent stills when on-site recycling is practiced, and bottom sludge that arises in cleaning the scouring equipment.

3.2.3.3 Water Releases. Chlorinated solvents may be released to water when the fabric is rinsed with water after scouring, as a result of vapor control and water/solvent separation, or when the dyestuff and printing chemicals containing chlorinated solvents are mixed with the wastewater form other parts of the plant.

Wastewater from scouring and rinsing contains natural and processing impurities removed by the hot alkaline detergents or soap solution used in scouring. The waste contains significant levels of BOD, dissolved solids, oil and grease and color. Processing of synthetics alone requires only light scouring, and the waste has lower BOD and dissolved solids, but shows significant increases in COD.

Wastewater concentrations from dyeing and printing are dependent on the process and the various add-ons used. Printing and dyeing wastes are comparable in many respects. In addition to color, the waste can contain high concentrations of BOD and dissolved solids. Printing pigments also introduce suspended solids into the waste stream. Waste flows from finishing are low. Chemicals are applied by padding, followed by drying and curing. The chemicals used are diverse, but only small amounts of them enter the wastewater, and the intent is to capture a very high fraction of the active agent on the cloth.

Combined waste from woven fabric finishing mills usually contains 250 to 850 mg/l BOD, 45 to 475 mg/l TSS, 425 to 1,440 mg/l COD, and has a pH of 7 to 11.

The major chemical used ion scouring cotton, caustic soda, appears in the wastewater stream. A surfactant and a small amount of sodium phosphate are frequently used, and these also appear in the waste stream. The waste also contains cotton waxes (about 3 to 4 percent of the cotton used). Consequently, scouring liquors are strongly alkaline (pH greater than 12), and dark-colored due to cotton impurities. They contain significant levels of dissolved solids and oil and grease. A modest level of suspended solids results from the presence of cotton impurities. The natural cotton impurities removed from greige fabric by scouring contribute BOD and are biodegraded rapidly.

The scouring of raw wool produces two major waste streams, the scour liquor and the rinse water. The scour liquor comprises 30 to 50 percent of the total waste flow and contains most of the material, acquired and applied impurities from the grease wool. Waste scour liquor is high in BOD, COD, solids, and grease and is turbid brown in color. Sulfur and phenols or other organics may also appear in the liquor.

3.2.4 Other Toxics

More subtle problems can arise in relationship to the potentially dangerous degradation products of textile (and other) dyes. An example of such a dye is food red #5 which is known to degrade to products that are carcinogenic and mutagenic. In this case, the dye itself is not harmful, but the degradation products that might occur during metabolism (or in the case of a textile dye, reductive stripping or other degradation) are suspect. However, chemical analog substitutes may be available to give safer dyes, in terms of degradation products.

One common type of procedure used in essentially all commercial dyeing operations is "stripping", or removal of colorants from textile substrates for repair purposes. There are many procedures that can be used for this purpose, and each one has its own unique features. Some important points of variation are:

- finish removal (liberates formaldehyde)
- pH (acid or alkaline)
- oxidation or reduction bath
- type of oxidizer/reducer
    - chromium based (Dichromate)
    - zinc based (Parolite/Discolite)
    - chlorine containing (Chlorite, Hypochlorite)
    - peroxy types (Peroxide, Perborate)
    - manganese based (Permanganate)
- use of aromatic solvents and/or surfactants as stripping assistants, such as phenolic materials, biphenyl, orthodichlorobenzene, etc. These may become polychlorinated to form toxic materials or degraded to produce lower molecular weight phenolic materials.

For stripping to be successful, colorants must be degraded to water soluble products and/or rendered colorless. This means, in most cases, that the chromophore part of a dye molecule must be degraded into products that, in most cases, are similar to the dye intermediates from which the colorant was synthesized. Some of these are hazardous materials, and stripping waste containing these are discharged to the effluent stream. Naturally, the specific type of stripping procedure and original colorant selection will determine the products that will be in the effluent.

Furthermore, all batch dyeing operations discharge spent dye liquors containing typically 5% to 15% of the total amount of dyestuff that was used. This occurs because batch dyeing is an equilibrium process and therefore some residual dye will always be left in spent dye liquors. These could also be degraded in waste treatment systems to the same kind of products that are produced by stripping.

3.3 SOURCES OF ALKALINITY/ACIDITY; PH

An analysis (similar to the previous discussion of BOD or toxics) can be made for pH contributors. Typical textile mills have several sources of acids and alkalis.

The control of effluent pH can be a difficult problem to handle from a process point of view because in many cases there is simply no substitute for the use of alkali or acid. This means that reuse, recovery, recycle or pretreatment (equalization and/or neutralization) are sometimes the only alternatives.

Reuse/recycle potential does exist in certain waste streams, and these are discussed in a general way in the following paragraphs. Of course, the details of any such system will be very product- and site-specific.

Preparation processes include several steps. Desizing of starch sized fabrics contributes little or nothing to alkalinity/acidity of waste streams. Other sizes, such as CMC, PVAc, PVOH, and PAA are typically removed in alkaline solutions. The contribution of these desizing processes can be a significant portion of total alkalinity. Since the desizing process is usually done continuously, waste streams can easily be neutralized by the addition of acid as produced. Source reduction would involve minimizing the amount of alkali used: usually, little is needed.

Scouring and bleaching of synthetics should be done using minimal amounts of alkali, but scouring of cotton requires large amounts of alkali. When cotton scouring and/or bleaching is done in a continuous process unit, there is potential for neutralizing or reuse of waste streams. Typical concentrations of alkali for cotton scouring are 2% to 4% of caustic (50%) based on the weight of the fabric processed.

Perhaps the greatest potential source of alkali in preparation is the process of mercerization of cotton. This uses caustic concentrations of about 20%. Wherever a significant amount of fabric is mercerized, the potential for caustic recovery as a source reduction strategy should be considered.

Dyeing processes vary in acidity/alkalinity depending on the substrate and dye class. General practice for the exhaust dyeing of various classes is:

- Acid for nylon and wool - exhaust from weakly to strongly dyebaths (pH 3 to 7), usually using formic acid, acetic acid, or a buffer salt for pH control.
- Basic for acrylic and copolymers - exhaust from weakly acid dyebaths (pH 4 to 5), usually using acetic acid for pH control.
- Direct for cellulose - exhaust from weakly alkaline baths (pH about 8), usually using soda ash for pH control.
- Fiber reactive for cellulose - exhaust from neutral baths with massive amounts of salt, then cause reaction to occur by adding large amounts of alkali such as caustic, soda ash, silicate and/or TSP. The pH will typically be above 10.
- Naphthol for cellulosic - prepare a diazo salt in a strongly acid (pH < 3) bath, then react with a S-napthol coupling agent. Effluent is very acidic. This applies also to other diazotized and developed colors.

- Vat and sulfurs for cellulose - typically exhausted in such a way that the effluent is alkaline, then oxidized.

- Disperse for synthetics - exhausted from weakly acid (pH 4.5 to 6) solutions.

- Practices for dyeing blends vary from the above.

Stripping and machine cleaning procedures can produce extreme pH variations.

One of the most difficult problems facing U.S. textile dischargers can be meeting typical POTW pretreatment regulations. Possible strategies include reuse of continuous streams, recovery systems for caustic (mercerization), and minimizing amounts of alkali used in varying processes. However, a typical mill that scours, bleaches, dyes and finishes cotton and blends has little or no chance of staying in the 6 to 9 pH range. Typical average values are above pH 11. This means that some pretreatment is necessary and that equalization alone will generally not be enough.

3.4 SOURCES OF AIR EMISSIONS

Although the primary emphasis in this document is water-borne waste streams, air emissions will be discussed here briefly. Air emissions emanate from several places in typical textile operations:

- hot air dryers
- dyeing machines
- storage tanks
- warehouse area
- fugitive (general ventilation)

One important waste product from finishing is air emissions from high temperature drying and curing ovens. Typically these contain varying amounts of volatile components of the finish mix as well as any volatile residues left in fabric from prior processing. Proper preparation and judicious selection of preparation, dyeing and finishing agents can help reduce these. The primary emphasis in this area has been use of abatement equipment rather than source reduction. This can sometimes be combined with heat recovery from air exhaust to provide a return on investment.

Of course, a textile processor has no way of knowing with certainty whether or not chemicals are being emitted without testing each potential source. However, estimates can be made, keeping in mind knowledge and records of major production chemicals used in specific processing. Material Safety Data Sheets (MSDS) would be an adequate guide to the components of a formulated chemical specialty.

Two chemicals, acetic acid and formaldehyde are emitted in essentially all textile operations. Acetic acid could be emitted from bulk storage tanks and, to a lesser extent, it is possible that it may be emitted from dyeing machines and/or driers. The emissions from bulk storage tanks would be through the vents and would occur during filling and due to breathing losses. There are methods which can be used to estimate these bulk tank emissions. Calculations show that one could expect that any large acetic bulk storage acid tank will emit amounts of vapors that exceed the "trace" limits, if not equipped with abatement equipment. As to the driers and dyeing machines, one would expect that the emissions will be well below the trace amounts. This could be verified by testing.

Formaldehyde may be emitted from bulk resin storage tanks, finished fabric warehouses, driers, and curing ovens. Emissions from bulk storage tanks may be above the trace amount limits. As to the emissions from driers, this also may be expected to be above trace amounts. To dry and cure all resin treated fabric on one oven will limit a processor to only one source. If several ovens are used and each emits formaldehyde above the trace amounts, each must be analyzed as a separate source. To be absolutely sure of the emission levels, testing could be done. It is not possible, in general, to estimate how much formaldehyde would be released in curing or warehouse storage, however, it may be significant.

Drager tubes are inexpensive tools that can be used to estimate emission rates of specific chemicals from textile facilities.

CHAPTER 4
POLLUTION PREVENTION STRATEGIES[1]

There are several pollution prevention (source reduction) strategies that have successfully been used, including

- Process Modification
- Use of Alternative Methods
- Chemical and Water Conservation
- Chemical Screening and Substitution

4.1 PROCESS MODIFICATION

Process changes and the implementation of new process technology are modifications to the basic manufacturing operations of a mill. Some reduce water use and eliminate or minimize the discharge of high strength or toxic chemicals. Others provide for material and energy reclamation. One new technology, water jet weaving, requires additional water, although the wastewater generated is relatively low in pollutant concentration.

Adoption of process changes and new process technology offers the greatest opportunity for reducing hydraulic and pollutant loads from textile mills. Technological advances in fibers, process chemicals, other raw materials and processing equipment are constantly occurring and, in general, these changes are resulting in lower hydraulic and conventional pollutant loadings.

---

[1] This chapter is derived from the following documents:

North Carolina Department of Environment, Health, and Natural Resources, *Identification and Reduction of Pollution Sources in Textile Wet Processing*, by Brent Smith, Department of Textile Chemistry, North Carolina State University: Pollution Prevention Pays Program, 1986.

Source Reduction Research Partnership, *Textiles Manufacture - Source Reduction of Chlorinated Solvents*, prepared for California Department of Toxic Substances Control and the USEPA Office of Research and Development Risk Reduction Engineering Laboratory, June 1991.

United States Environmental Protection Agency, *Development Document for Effluent Limitations Guidelines and Standards for the Textile Mills - Point Source Category*, EPA 440/1-82/022, September 1982.

59

Solvent processing is an example of a new process technology. It involves the use of a nonaqueous solvent such as perchloroethylene to scour and dye fabric. Because the solvent has a high vapor pressure (compared to water), it is possible to vaporize it more easily and recover it for reuse. It has not, however, achieved the original expectations of performance, except for specialized processing and small batch operations. Effective applications include solvent scouring of wool fabric and some synthetic knit fabrics and solvent finishing of upholstery, drapery, synthetic knits, and fabrics that are sensitive to water.

There are a number of reasons for the limited application of solvent processing to date. The most troublesome problem is that the value of the recovered solvent is often less than is necessary to make the process economically feasible. In addition, only a limited number of the thousands of different dyestuffs and chemicals now used in commercial textile processing can be transferred directly to solvent use. Another problem is the emission of unrecovered solvent to the work place or the atmosphere.

A more common method of reducing hydraulic and pollutant loadings in the industry is changing process and material flow procedures. Continuous operations generally require less space, water and process chemicals than do batch operations. Circulating baths and rinses also require less water. Rope washers are reportedly more effective than open-width washers in reducing water use. Significant water use reductions also are achieved by combining separate operations, such as scouring and dyeing in the finishing of synthetic fibers and the desizing and scouring of cotton fibers.

Some of the newer textile processing equipment results in lower water and chemical usage. For example, pressure dye machines use dyestuff more efficiently, reduce water requirements and reduce the level of toxic dye carriers required in atmospheric dyeing. It is reasonable to expect that the textile processing equipment of the future will be even more efficient in the use of water, chemicals and energy.

Several methods are available to the manufacturer to reduce these pollutants from waste streams. They include:

- Reduction of chemical use
- Chemical substitution
- Recycle/renovation of batch treatment baths
- Waste stream reuse
- Recovery of chemicals from waste streams
- Use of alternative processes

- Treatment of waste streams (separate and/or composite)
    - equalization
    - neutralization
    - screening
    - etc.

In many cases, it is possible to reduce the amounts of chemicals used in textile processing without significant effect on product quality. Frequently overused materials include defoamers, surfactants, lubricants and similar types of chemical specialties.

In the case of chemical substitutions to reduce waste loading, the situation is not well defined. several problems complicate the situation including:

- Lack of BOD, toxicity, and other data from suppliers
- Difficulties in correlating data on pure products to estimate effects in spent dye liquors and other waste streams
- Difficulties in evaluating trade-off effects such as BOD vs toxicity
- Proprietary nature of chemical specialties

One way to evaluate the potential for oxygen demand/toxicity problems for a product or waste stream is to take into account both the COD and BOD of the material. These quantities are related in such a way that COD:BOD ratio is 2.5:1 to 5:1 for typical textile waste streams. Any waste stream that has very high (above 5:1) COD:BOD ratio indicates poor biodegradability of material. In many cases, BOD alone is not an adequate indicator of biodegradability. This subject has been studied for many types of textile chemicals, including PVA, butyl benzoate, polyethylene, kerosene, and dyes such as direct blue 80, disperse red 68, disperse blue 139, and others.

In many cases, the overall waste situation is not improved by substitution. For example, the previously mentioned case or substitution of certain surfactants can result in lower BOD but increased toxicity of treated wastes. In other cases, materials exhaust from the batch and become (temporarily or permanently) part of the product. During drying or other high temperature processes, VOCs may also be emitted. Another example of trade-offs is the use of mineral vs organic acids/alkali which can substitute BOD for acidity/alkalinity, which may help in specific cases. The use of epsom salts as an antimigrant can replace copper or organic resins as a dye fixative.

Finally, there are opportunities for overall reductions, including:

- Reduce chemical usage
- Use synthetic sizes
- Recovery
- Stream reuse
- Dyebath renovation/reuse
- Process modification.

4.1.1 Chemical Substitution Overview

The objective of chemical substitution is to replace process chemicals having high pollutant strength or toxic properties with others that have less impact on water quality or that are more amenable to wastewater treatment. A number of process chemical substitutions have been suggested or developed for the textile industry, and it is expected that this area will play a more important role in the future. The cost to substitute other chemicals and products for those containing toxic pollutants is usually much less than the cost to remove the pollutants from a mill's discharge via end-of-pipe treatment. For any substitution, however, a careful evaluation should be made to assure that one pollution problem is not being substituted for another.

Foaming problems in treatment facilities and receiving streams have been solved by substituting biodegradable, low-foaming detergents for the so-called "hard" detergents. Potentially toxic pollutants have been reduced or eliminated by substitution. For example, switching from chromate oxidizers to hydrogen peroxide or iodates eliminates chromium in dyeing processes. The replacement of soap with sulfuric acid in wool fulling operations is a substitution that results in lower BOD loadings. Mineral acids are substituted for high BOD acetic acid in dyeing processes offering an advantage in terms of wastewater treatability. The substitution of mineral oils with nonionic emulsifiers for the more traditional olive oil in carding wool also results in lower pollutant levels.

Starch wastes from desizing are the single greatest source of BOD at many mills. Consequently, substitutes with low BOD, such as CMC, PVA and PAA, have become useful to reduce BOD loadings on wastewater treatment systems. However, another consideration is the net effect on the environment. These low BOD, high COD sizes contribute substantially to the ultimate oxygen demand of the wastewater. In view of this, the following from a report prepared for the American Textile Manufacturers Institute is pertinent.

> "Substitution should assume the direction of easily treatable materials in terms of waste control technology and recoverability. Chemists and environmental engineers must work together in considering which process chemical is best handled by the means or unit process most efficiently suited to its recovery or removal. Certainly, in terms of conventional biological systems, low BOD

> chemicals will not lose their significance. However, as physical-chemical treatment methods are adopted, other characteristics (COD, ultimate BOD, solids, toxic pollutants, etc.) will likely become increasingly important. Additional research is necessary to determine the viability of COD versus BOD substitutions and the economic and treatability impact of such cursory changes."

Chemical substitutions for dyes requiring chromium mordants and chromate oxidizers are most commonly used. One wool finishing mill reported that savings in labor and other processing costs more than offset the higher cost of the dyes substituted for the traditional chrome dyes. BOD reductions were achieved at some mills by substituting synthetic warp sizes for starch, using low BOD detergents for those with high BOD, and eliminating the use of acetic acid as a pH adjuster.

The following sections (4.1.2 through 4.1.4) discuss each wet process in detail.

4.1.2 Preparation

Preparation processes, especially desizing and scouring, can be done on many types of equipment, both continuous and batch. The continuous processes have a somewhat greater potential for waste stream reuse since the waste stream is continuous, fairly constant in characteristics, and usually easy to segregate from other waste streams.

Examples of waste stream reuse in a typical bleach unit processing polyester/cotton and 100% cotton fabrics would include

- Recycle J - box or kier drain wastes to saturator
- Use of countercurrent washing
- Use of washer waste from scour operation for batch scouring

This is shown in Exhibit 4-1. Of course, preparation chemicals (including especially optical brighteners and tints) must be selected in such a way that reuse does not create quality problems such as spotting.

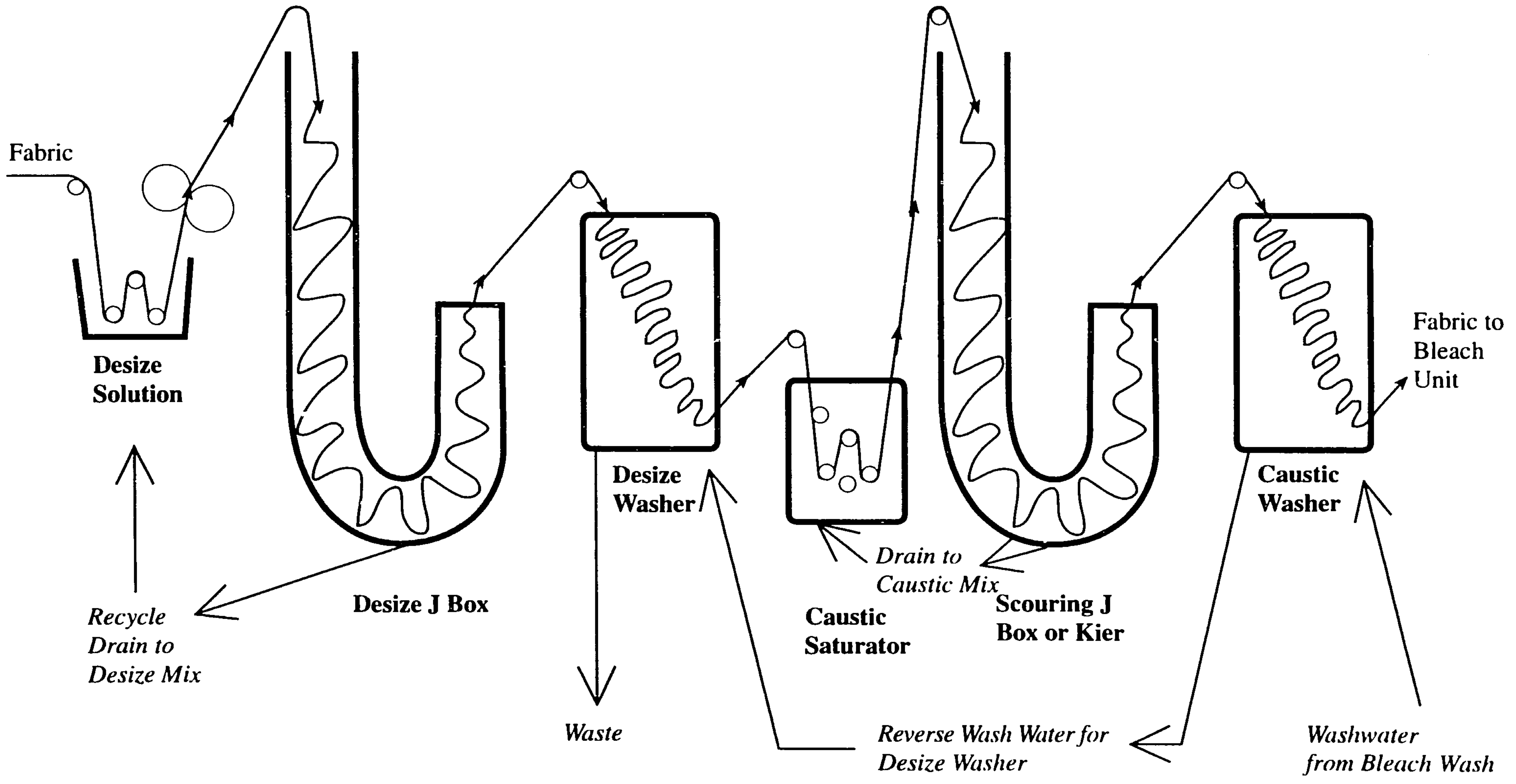
The situation with batch scouring and bleaching does not allow, in general, for recycle/recovery of waste streams because:

- The streams occur intermittently.

- The streams generally dump into pits and are not easily segregated.

63

Exhibit 4-1
Waste Reuse/Recycle in Continuous Preparation Unit



- The liquor ratios are much higher (typically 10:1 to 20:1) in batch preparation; therefore, the wastes are more dilute.
- Preparation steps are frequently combined.

4.1.3 Dyeing

With dyeing processes, the following should be considered in making product substitutions.

Does the product, or portions of the product, exhaust? Many products such as dyes, dye carriers, softeners, lubricants, and retarders are blends. Some components may exhaust while others do not. For example, disperse dyes and colorants are commonly diluted with dispersants such as napthaline sulfonic acid to make commercial dyes. The colorant will exhaust leaving the dispersant in solution. Thus, the BOD of the commercial dye is an indicator of the BOD load in the waste only to the extent that the dispersant contributes.

For dyes, this would vary. For softeners, lubricants, dye carriers and other emulsified products, the emulsifier system would be a major contributor, since it generally would not exhaust. The active materials (softener, carrier, etc.) would exhaust to various degrees. This means that the dyer must examine not only the BOD of a product but also the BOD that is left in a residual dyebath after using a product.

The portions of a product (especially carrier) that exhaust will become part of the substrate, usually temporarily, until the substrate is dried at high temperature. Then these materials may become airborne waste (VOCs and PRs, typically), Examples of these materials are trichlorobenzene, dichlorobenzene, biphenyl, methyl naphthalene, orthophenyl phenol, and butyl benzoate.

Reduction strategies in this area would include:

- Get as much information as possible from vendors.
- Analyze spent dyebaths for residual materials.
- Be aware of potential problem chemicals such as aryl phenol ethoxylates, branched alkyl phenol ethoxylates, chlorinated aromatics, and metals.

As pointed out above, the surfactant/dispersant/emulsifier content of products is a major contributor to BOD waste load because:

(a) they do not usually exhaust,
(b) surfactants have relatively high BODs.

65

However, as in the case of scouring processes, lower BOD surfactants may not necessarily be desirable since they may contribute more to aquatic toxicity or treated wastes than the more degradable (higher BOD) surfactants.

Because of the widespread use of carrier materials (including "levelers") used for dyeing synthetic fibers with disperse dyes, and the high potential for contribution to waste loads, both water (BOD/COD/toxicity) and air (VOC/PR), careful consideration of carrier selection is necessary.

Exhibit 4-2 shows the BOD of some specific carrier-active materials.

As an example of dye batch chemical substitutions, dyer was having problems with blotchy dyeings on jet dye machines. These problems were being caused by foaming of the dye bath due to excessive amounts of chemical specialties. To solve this problem a new "product" was substituted for all the other specialties already in the bath. This new "product" was nothing but water. This resulted in savings in cost, off-quality, and pollutant discharge.

Exhibit 4-2

Material	BOD
Benzoates	1,250,000
Monochloro benzene	30,000
Orthophenyl phenol	6,000
Salicylates	24,000
Phenyl methyl carbitol	19,000
Phthalates	1,060,000
Xylene	0

4.1.4 Finishing

It is good practice to try to reuse the residual portions of finish mixes as much as possible by adding back to them the required components to make up the next mix. This is practiced commercially in many mills and saves both the pollutant load to the waste stream plus the cost of the materials saved. A simple technique to facilitate the dilution calculations is Pearson's Square.

Another strategy (for water conservation) is to return noncontact cooling water and steam condensates to either a hot water holding tank or a clear well. If neither of these is possible, segregate the waste streams from these sources which do not generally require treatment from other waste streams that do. This reduces hydraulic loads in treatment systems.

4.2 PAD BATCH DYEING

The pad batch (cold) method of dyeing cellulosics. It has been used quite successfully in a wide variety of applications. Benefits include essentially eliminating the need for salt or chemical specialties from the dyebath, with associated reduction in cost and pollution source reduction. In many ways, it is one of the most reliable and easiest-to-control methods available today for certain applications. Strangely enough, however, it has not caught on in this country to the extent that it is used in Continental Europe or in England.

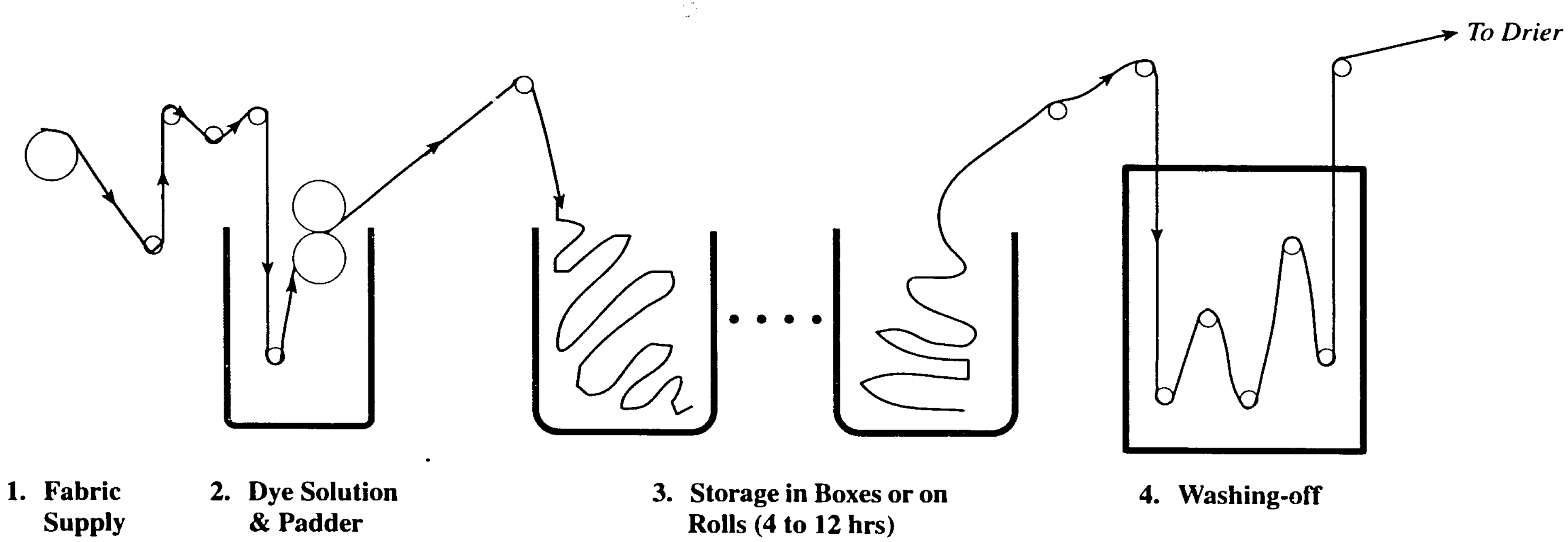
To summarize the pad batch method, prepared fabric is impregnated with liquor containing premixed fiber reactive dyestuff and alkali; excess liquid is squeezed out on the mangle; the fabric is batched onto rolls or in boxes, and covered with plastic film to prevent absorption of $C0_2$ from air or evaporation of water, then stored for two to twelve hours (see Exhibit 4-3). The goods can be washed off in any of several conventional ways, depending on equipment available in the mill.

The method is interesting because it offers several significant advantages, primarily in its simplicity and speed. Production of between 75 and 150 yards a minute, depending on the construction and weight of the goods involved is commonly reported. In fact, this kind of speed can make the limiting factor the wash-off facilities, which may not be able to keep up.

Another factor that has generated enthusiasm for pad batch is its flexibility, compared to a continuous range. Either wovens or knits can be done, and in many constructions. Frequent changes of shade are no problem because reactives remain water soluble, making cleanup easy. This fits many situations well, especially when versatility is required. The pad batch system can run the same cold dyeing fiber reactive combinations that are usually run on package dye, jigs, beams, becks, jets and other equipment. Washing-off can be done with becks, beams, continuous equipment or other available machines.

Studies have shown that pad batch dyeing for cotton, rayon and blends conserves energy, water, dyes and chemicals, labor and floor space. Water consumption for pad batch dyeing with beam wash-off is typically under two gallons per pound of dyed fabric, compared to typically 20 or more on atmospheric becks for the same fiber reactive dyed shades. Energy consumption is similarly reduced from about 9000 BTU's per pound of dyed fabric for becks to under 2000 BTU's per pound for pad batch with beam washing. Chemical use, and associated BOD and COD loadings for waste streams, can be reduced up to 80% compared to atmospheric becks.

Exhibit 4-3
Pad/Batch, Storage and Wash-off Unit



Labor costs are also reduced. For example, two workers per shift can dye 200,000 pounds of fabric per five-day week.

In general, the quality of pad batch dyeings is much better than other dyeing systems. Pad batch dyeings require highly reactive "cold dyeing" fiber reactive colors. Examples of brand names of such colors are:

Atlafix CX	(Atlantic)
Cibacron F	(Ciba Geigy)
Intracron C	(C&K)
Levafix E(A)	(Mobay)
Drimarine K	(Sandoz)
Procion M	(ICI)
Remazol	(Hoechst)

One key to successful use of the system by the dyer is pH control. While all respective dyes are not all equally sensitive, a pH of 10.5 to 11.5 will be ideal in most cases for 12 hour batching. An increase in pH may be necessary to increase reaction rate for short batch times (2 to 4 hours).

Extensive work in developing the pad batch system of dyeing cellulose has been done in the U.S. by Cotton Incorporated. Some of the following information was developed by them in actual plant experience.

Equipment for the pad batch dyeing consists of:

1. Padding unit
2. Batcher or material handling system
3. Dye/alkali mixing device
4. A-frames, storage racks or storage boxes
5. Wash-off device (beam, beck, continuous, etc.)

The padding unit should have the necessary controls for handling the type of fabric that is to be dyed on the unit. In case of knit fabrics, the padder must have adequate guiding, decurling and spreading equipment to handle the knit in open width form. This is especially important on single knit and warp knit fabrics which tend to curl when lengthwise tension is applied. The padder should also have suitable pressure controls to allow the nip to be controlled consistently. A deflection roll padder may be advantageous. Another desirable feature is a small dye trough. This is important to achieve good dye liquor turnover, to minimize the amount of "tailing", and also to avoid reactive dye hydrolysis which might produce shading from beginning to end of the fabric run. A dye trough of ten gallon capacity or less is usually recommended. Adequate speed controls which control the padder and synchronize the batcher unit are absolutely necessary.

In order to obtain a quality dyeing, uniform from side to side and end to end, the fabric must be uniformly prepared. The fabric should be scoured and/or bleached with a residual pH of 7 or slightly less. It should contain no residual alkali, starch, knitting oils or any other foreign substance which will interfere with the evenness of absorbency or the subsequent colorfastness of the fabric. The fabrics muse wet out rapidly and uniformly and must be uniformly prepared and dried. It is advantageous to make up dye lots of fabrics which were prepared together to avoid possible shade variation within the dye lot.

Pad batch dyeing gives much lower defect levels than rope dyeing on many styles. For example, fabrics of varying thickness such as 100% rayon jacquard tablecloths are difficult to process in rope form without streaking if dyed by exhaust methods on becks using direct dyes.

The beauty of the pad batch system using the high reactivity dyes is that a great deal of the dye fixes in 30 minutes, and the difference in depth between one hour and eight hours is negligible in many shades. This is one reason for the unusual degree of shade reliability and is important because the fabric near the core of the take-up roll is obviously first on and last off, and has actually batched longer than the outer layers.

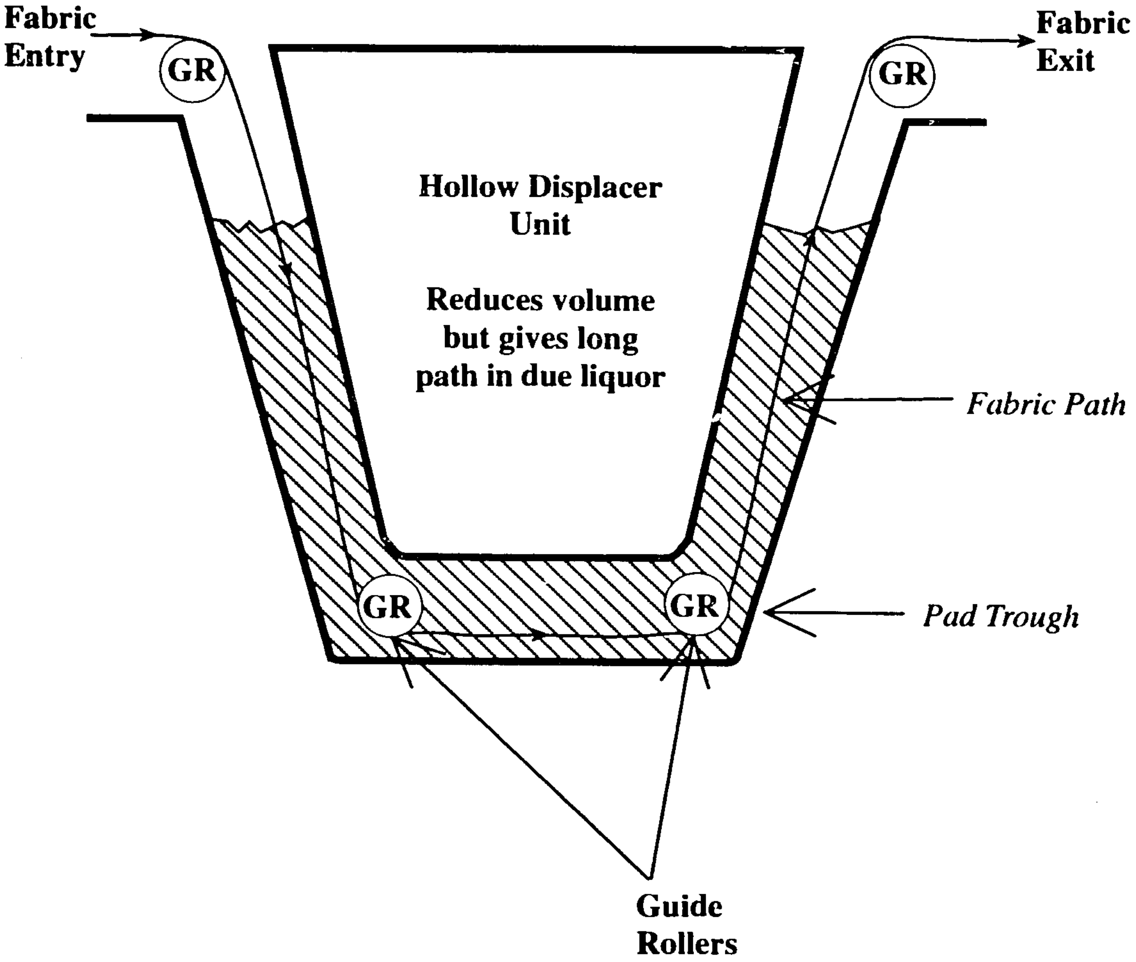
Because of the low physical affinity of these cold dyeing reactives, they work extremely well for all continuous operations that include a padding sequence. Color yield (exhaustion and fixation) tend to be lower when dyeing in a long liquor, compared with high affinity dyestuffs such as vat dyes. A worthwhile increase in fixation can be accomplished in a shorter liquor.

The advantages of this rapid fixation and stability of shade are obvious when compared to other methods. In jig and beck dyeing, for example, the normal routine is to continue dyeing, shading if necessary, until the correct color is obtained. Dyehouse operators are seen constantly cutting swatches off the goods for inspection. Even when the dyer is satisfied with the color, it may be that all fixable color has not reacted with the cloth, so that each batch must be treated individually, and shade variations are inevitable. With pad batch, however, experience has shown that if padding and batching temperatures are properly controlled, reproducibility of shade is outstanding.

There is still another benefit of this rapid fixation. It is a minor point perhaps, and easily overlooked, but there is almost 100% reproducibility from lab to production shades. The pad batch system may be home design, but it must feature accurate in mixing and metering. Two tanks hold dyestuff and alkali solutions which are fed to a mix and dispensing mechanism with a proportioning device. The mix is then fed via a pump to the pad unit. By employing a hollow dispenser, it is possible to keep the passage through which the fabric passes less than one inch wide. This keeps the volume of liquor very low, about eight gallons or less, and insures the rapid turnover of liquor so that dye decomposition is kept to a minimum. This is, of course, important because adding the alkali to increase reactivity also affects the stability of the liquor. (See Exhibit 4-4.)

70

Exhibit 4-4
Pad with Displacer



In working with plant production pad batch units, the following four point checklist has been helpful in avoiding problems:

1. Keep good alkali control by insuring adequate mixing and/or metering techniques.
2. Adjust exhaust dye recipes for pad batch by keeping accurate data on liquor ratios. Keep the immersion long, the liquor ratio short, and the volume low in the pad.
3. Have good preparation. Actually, pad batch reliability has reached the point where it can be used as a check on the preparation. If something doesn't look right, most often it can be traced to mistakes in preparation.
4. Keep good temperature control, especially avoid dyeing hot fabric fresh from preparation. Feed cold fabric to the pad or else the temperature will rise. During very hot weather, keep the mix cool with a cooling water jacket or use ice in the mix.

Since many U.S. mills that have agreements with municipal sewage systems pay on some formula based on the content of BOD, COD or other undesirable contents of the effluent, the pad batch method employing cold reactives is also attractive from the pollution source management standpoint. Reactives do not require reducing or oxidizing agents, as do vats or sulfurs. Reactive dyes require use of massive amounts of salt when employed in becks, but in the pad batch method, cold reactives require no salt at all.

The use of chemical specialties such as lubricants, leveling agents, antimigrants, fixatives, defoamers and other specialties by pad batch dyeing is usually not required. Small amounts of detergent are used in washing-off.

In summary, excellent results have been obtained with the pad batch (cold) system utilizing high reactivity dyes. Dyers have experienced many benefits:

1. Reduction in waste loads in effluent
2. Low capital outlay
3. Low energy requirements
4. High production speed
5. Reduced labor requirement
6. High color yield
7. Outstanding reproducibility
8. Excellent penetration, and leveling characteristics
9. Rapid fixation
10. Substantial overall cost savings (dyes, chemicals, labor)

12

At their inception in 1956, fiber reactives were noted for their exceptionally bright shades. However, the range has increased dramatically. The shade range now includes new dyes of muted tones aimed at shades that previously were considered the domain of direct, sulfur and vat dyes. Reactives have given a good account of themselves in terms of fastness and economy against traditional classes of dyes, and future prospects appear very bright indeed.

4.3 WATER CONSERVATION

One area that can usually render both cost savings and pollution management through source reduction for textile mills is the practice of water conservation. It is not unusual to find situations where 10 to 20% reduction in water use can be realized.
Commonly observed sources of water waste are:

- hoses left running
- broken or missing valves
- cooling water left running when machinery is shut down
- defective toilets, water coolers

Several methods have been used to recover and/or segregate waste water streams. Once-through noncontact cooling water can be reused by sending it back to a clear well or influent water line to the mill. This can result in significant water savings.

Waste streams from roof drains and parking lot drains, from cooling water sources, from process waste water, and from domestic waste can sometimes be segregated, treated, and discharged separately to a mill's advantage. Details are usually site-specific.

Most waste water from textile wet processing is from washing operations, primarily in preparation or dyeing. Since preparation processes are typically continuous, well-known techniques such as countercurrent washing can be used to great advantage for water conservation in these washing processes.

While water reuse is the use of the same water more than once, water use reduction is the elimination of unnecessary water consumption. Three in-plant control measures that are considered forms of water use reduction are: 1) countercurrent flow washing or rinsing, 2) conservation, and 3) process modification.

The countercurrent flow system is based on the principle that wash water is not used effectively if it is cleaner than the fabric when the water leaves the washbox. In countercurrent flow applied to operations such as wash boxes on a continuous range, the water flows through the process in the direction opposite to that of the material. As the water passes into each box, it contacts material containing increasing amounts of impurities and other undesirable matter. This system is considered standard procedure in wool scouring and is not an uncommon practice at finishing mills that scour, mercerize, bleach, or dye on continuous ranges. At some of these mills, countercurrent flow wash boxes have been used for a long time. However, many mills still do not use countercurrent flow, especially where water is inexpensive. This practice is expected to change as water and wastewater treatment become more costly.

Conservation measures include a variety of steps that can be taken to reduce water use in textile mills. They consist primarily of maintaining close control over mill operations to avoid accidental loss of process chemical baths and avoiding the preparation of larger batches than required. Supervision to insure efficient operation of in-plant controls, such as the countercurrent flow systems discussed above, is an important conservation technique. Reduction of dirt, grease and rust in production areas to avoid unnecessary washing and processing of soiled material also contributes to conservation. Other measures that are used are the construction of retaining walls, splashboards and sills, and proper maintenance of machinery and plumbing to minimize process fluid losses through spillage and leaks. Use of liquid level controls, flow indicators and meters and automatic shut-off devices also reduce water requirements at textile mills.

Simply implemented process modifications that reduce water use include longer process runs between dumps and modulation of water supply to match the speed of the textile products being handled. Carefully supervised trials should be run to determine minimum water requirements possible without reducing product quality. Instrumentation and automation can be incorporated into processes to assist in uniformity of application, reduction of rework, control of operating parameters, e.g., pH and temperature, or similar functions may be used to achieve reductions in water and chemical use.

Based on questionnaire and telephone surveys, the most common water use reduction measure identified was countercurrent flow of water during wet processing operations. Countercurrent flow in scouring and desizing, and the use of rinse water in bleaching, dyeing and mercerizing have been instituted at various U.S. mills. Energy and water savings can be substantial, but installation costs can vary considerably.

Some mills can use chemicals in operations such as scouring and dyeing (continuous type) for longer periods without dumping. For example, one mill has recently extended the time between scour dumps from once every 2 hours to once every 24 hours without affecting quality. More extensive modifications that result in lower water use generally require process changes and are discussed later in this section.

4.3.1 Water Consumption of Batch Dyeing Machines

Different types of dyeing machinery use different amounts of water. There are many "low liquor ratio" dyeing machines which are purported to save water. The liquor ratio is the ratio of amount of water (in pounds) in the exhaust dyebath to amount of fabric (in pounds). This differs greatly between machine types. However, most water in dyeing operations is used for washing, and not in the dyebath itself. Thus it is not necessarily true that a dyeing machine with 10:1 liquor ratio will use half as much as a dye machine with 20:1 liquor ratio. Exhibit 4-5 shows typical values for liquor ratios and water consumption for various types of dyeing machinery.

Exhibit 4-5

Dyeing Machine	**H_20 consumption gal/#**	**Typical liquor ratio liquor/goods at time of dye application**
Continuous	20	1:1
Beck	28	17:1
Jet	24	12:1
Jig	12	5:1
Beam	20	10:1
Package	22	10:1
Paddle	35	40:1
Stock	20	12:1
Skein	30	17:1

In general, the heating of dyebaths constitutes the major portion of the energy consumed in dyeing; therefore, low liquor ratio dyeing equipment represents major energy savings. But the washing efficiency of many types of low liquor ratio dyeing machines, such as jigs, is poor. Washing efficiency depends on mechanical factors, such as bath and fabric turnover rate or "contacts", liquor ratio, turbulence and other mechanical considerations and physical flow characteristics. Thus, low liquor ratio and reduced total water use do not always correlate as closely as one might expect.

4.3.2 Solvent Processing

At one time, during the 1970s, great interest in the U.S. was expressed in solvent systems other than water for processing textiles. Solvent preparation, dyeing, finishing, and drying were closely examined by the industry. These did not meet wide acceptance due to two factors. First, chemical systems, dyes, specialties, etc. appropriate to solvent use were not available at commercially competitive cost. Second, environmental regulations on airborne emissions from solvent processing equipment, storage facilities, and hazardous waste regulations on recovery byproducts (still bottoms, etc.) made many solvent processes untenable. There are, however, certain instances where solvent processing can be used for source abatement.

4.3.3 Low Add-on Finishing

Foam processing (including mercerizing, bleaching, dyeing, finishing) is being successfully used for water conservation.

Other low add-on techniques, including engraved rollers, kiss-rolls, etc. have been used to reduce water consumption. However, these are mainly used in continuous processes where there is little or no water discharge anyway. There have been some experimental systems for foam dyeing such as the Sancowad process. These can reduce amounts of water used in exhaust dyebaths. As stated previously, this does not necessarily correlate directly to water use reduction.

Wet finish application procedures can be classified into categories:

- saturation express ion
- controlled application

Specific commercial application methods are shown in Exhibit 4-6.

Exhibit 4-6
Commercial Low Add-on Finishing Processes

Process	Category
Air jet pad	Saturation/expression
Curved blade applicator	Controlled application
Fabric transfer loop	Combination
Gas phase	Controlled application
High extraction pad	Saturation/expression
Kiss roll	Controlled application
Printing	Controlled application
Spray	Controlled application
Stable foam	Controlled application
Unstable foam	Controlled application

Process	Category
Vacuum systems	Saturation/expression
Wicking systems	Controlled application

Controlled low add-on processes have individual differences which result in specific advantages and limitations but, in general, advantages are gained in cost, productivity, quality and reduced water and chemical use:

Category	**Advantages**
Cost:	Faster dryer speed Less chemical use Lower energy use
Quality:	Improved hand Better fastness Better dimensional stability
Productivity	Faster dryer speed Wet-on-wet processing

Other advantages can be realized by specific methods.

4.3.4 Rapid Inverse Dyeing

One water conservation strategy which is widely practiced by dyers of polyester/cotton blended fabrics is rapid inverse dyeing (RID) using disperse and fiber reactive dyes. In the normal process of dyeing these blends, the steps are:

"FORWARD"

- Prepare fabric
- Dye polyester (disperse)
- Wash or reductive after clear
- Dye cotton (fiber reactive)
- Wash

The RID process dyes the fiber reactive portion first (on cotton) and utilizes the slightly acidic disperse dyebath as a wash for the fiber reactive. The dyeing process then becomes:

"RID"

- Prepare
- Dye cotton (fiber reactive)
- Dye polyester (and wash cotton)
- Wash or after clear

Other dyeing strategies involve combining the dyeing of two fibers in one bath (disperse/direct) for blends whenever possible, or combining the scouring and dyeing of synthetics or cotton (when strict shade requirements do not have to be met). These are widely practical and vary greatly with end use requirements (shade, fastness, etc.) and specific blends and/or equipment.

4.4 CHEMICAL SCREENING/INVENTORY CONTROL

An important part of waste management is raw material quality control. In many cases, undesirable wastes can result from raw material components and impurities that are not actually essential to the process, for example, metal contents of certain dyestuffs. Many companies, such as WestPoint Pepperell in North Carolina, have instituted raw material controls in several stages.

4.4.1 Prescreening

The first step in raw material quality control for five WestPoint Pepperell plant includes chemical prescreening.

In 1975 the company established a toxic chemicals committee to review products in use or under consideration and evaluate them according to a wide range of health and environmental impact criteria. The committee has proven to be an effective management initiative which has minimized hazardous waste production and the accompanying costs and environmental impacts.

In 1975, a committee was assembled which included a medical doctor, an industrial hygienist, three research chemists, a professional engineer, a corporate attorney, a corporate safety officer, a representative from chemical production, and a corporate information specialist In 1976, the committee began its evaluations. It reviewed both chemicals in use and new products considered for use.

Several criteria were used for evaluation in addition to the original considerations of personnel safety and fire hazard potential. These include:

- hazardous waste characteristics
  (ignitability, toxicity, corrosivity, reactivity)

78

- "priority pollutant" status
- availability of safer alternatives
- biodegradability
- heavy metal content
- potential for accumulation in the facility
- potential for release to the environment
- hazard potential when mixed with other chemicals
- proposed manner of use
- ultimate fate of the chemical
- hazard potential to the customer

Products under use such as hydrazine and hydrofluoric acid were eliminated due to limited ventilation.

Some of the new products considered by the committee and rejected include dichlorobenzidine dyes because of the benzidine base, and a chloride catalyst for resins because of its association with bis-(chloromethyl) ether. Another committee recommendation involved the substitution of a water-based cleaner for organic solvent cleaners.

When it was first organized, the committee scheduled regular quarterly meetings. Part of its function was to establish a set of workable procedures for each plant to follow prior to any chemical purchases Once these were in place, much of the committee's work could be handled in-plant. Currently, all new chemical purchase requests must be approved by the corporate research center chemist, who follows guidelines set forth by the committee.

WestPoint Pepperell is very satisfied with its chemical safety review program. They attribute their extremely low levels of hazardous waste production to the work of the toxic chemicals committee. They believe their costs are kept lower by controlling chemicals at the point in use and avoiding waste management costs. They currently generate only a small amount of spent solvent from a dry cleaning operation. The solvent is reclaimed out-of-house by a solvent recovery company.

4.4.2 Routine Raw Material Quality Control

The subsequent quality control of all incoming shipments of dyes and chemicals can be easily done using minimal equipment. One scheme that requires minimum amount of effort on the mill's part and also minimum amount of capital investment is the following

- Obtain a standard from the vendor for each chemical purchased.
- Perform several simple raw material tests on each drum or shipment of material as it is opened
    - (a) Move the chemical to a normal room temperature environment and allow to acclimate.
    - (b) Retain an appropriate sized sample (100 cc's is usually enough).
    - (c) Check pH with meter or paper and record.
    - (d) Check viscosity with Zahn cup and record.
    - (e) Check density with hydrometer and record.
    - (f) Note color and clarity visually and record.
    - (g) Note odor and record.
    - (h) Check index of refraction with handheld refractometer for clear liquids and record.
    - (i) Compare data to previous history and vendors standard values.
- Retest drums that have been opened for excessively long times.

By using these simple tests a manufacturer can detect significant variations in products which are supplied to him for production use. Examples of the types of commonly occurring anomalies that can be detected are mislabeled drums and changes in the formulation of a chemical specialty.

Chemical specialties are used in almost every textile operation and in most cases, the processor (dyer or finisher) does not know the actual chemical composition that he is using. Suppliers of chemical specialties do not reveal, and in some cases do not know, the composition of products they sell. In many cases, the composition of specialties can change without knowledge of the user. Two examples from actual mill experience:

Example I

A manufacturer of a solvent scouring specialty, consisting of emulsifier and xylene, changed the solvent composition to chlorotoluene for cost and labeling reasons when the Department of Transportation (DOT) and the vendor's insurance company began to require red labels and special handling for xylene. This had a profound effect on the mill's air emissions, water toxicity, and other aspects of production.

Example II

A vendor of disperse dye carrier formulated a product from emulsifiers, carrier-active solvents and a low molecular weight byproduct from polyester manufacture which was composed of a complex mixture of esters of cresotinic and other organic acids. Because of cost and availability considerations, the vendor changed from one manufacturer of polyester to another for the byproduct. This gave similar (but not exactly the same) dyeing results, but considerably different waste characteristics.

Example III

A chemical manufacturer mislabeled drums of dye fixative as wetting agent, causing massive dye spots.

Any of these situations could have been detected by the simple tests described above.

If the simple tests show unexpected variations in raw materials, then more sophisticated techniques, such as GC and/or IR analysis can be used on retained samples.

Dyestuffs and commodity chemicals can be controlled by techniques which are currently available or under development.

It is also a good practice to perform prescreening test protocols on chemicals which have been in use for a long time in order to verify:

- that the chemical use level and practice are correct and reasonable
- that new chemicals and regulations have not made the chemical under evaluation obsolete
- that duplicate chemicals (from a functional point of view) do not exist

4.5 REDUCTION OF METALS IN EFFLUENT

Metals are commonly used in textile processing in several ways. These include:

- oxidizers for vat and sulfur dyes
- copper aftertreatment for direct dyes
- metal catalyst for resin curing
- special finishes (flame retardant, water repellent)
- dye stripping
- internal distribution system and equipment

Also metals can be brought into processes by the fabric as components of:

- the fiber
- size materials
- fiber finishes
- waxes, oils, lubricants
- dirt or casual contamination of the fabric

This varies over wide ranges, but analysis of two cotton fabrics (after desizing and scouring) showed well over 175 ppm metal content. These were two 100% cotton fabrics that had been scoured and desized. In addition to these residual metals in the fiber, it is common to find high concentration of metals in processing baths 100 times higher than in the source water.

These metals that are in the source water frequently interfere with the textile process, causing undesirable effects and/or substrate damage, as well as contamination of waste streams. The water sources and most commonly occurring contaminants are:

1) well water
    - hardness (Ca++ and Mg++)
    - iron and other heavy metals
    - sulfide, cabonate, etc.
    - sediment and particulates
    - contamination from clear well

2) river water
    - as above for well water
    - tannic acid (seasonal)
    - pollutants from upstream dischargers

3) city water
    - all of the above (depends on city's source)
    - chlorine
    - treatment chemicals
        - copper, alum, etc.
    - sediment and other contamination from distribution lines

Internal sources, which can be controlled in order to reduce the production of metal-containing waste streams, include:

1) metals (iron and copper)
    - machinery
        - containment
        - feed lines
        - valves
    - copper plumbing
    - internal water treatment
        - potable/process
    - substrate (plus calcium and magnesium)

2) organics, acids, alkalis, and metals
    - live steam (boiler treatment chemicals)

Proper maintenance and the use of alternative structural materials such as PVC pipe instead of copper for plumbing can reduce levels of metals in waste streams.

Finally, there are substantial metal contributions for specific processing situations. It is possible, for example, to select dyestuffs with low metal contents to reduce discharges of copper, zinc, lead, etc.

The choice of oxidizer systems and aftertreatments for dyes is also important. These are directly related to dye application and are sometimes used to insure complete fixation, insolubilization, or entrapment of the dye within the fiber. An example of this is the use of copper sulfate to aftertreat direct dyes, rarely practiced now in favor of organic resinous fixatives. These resinous fixatives have higher nitrogen content and BOD, but have no copper content. An alternative procedure that avoids both heavy metals and BOD loading is to use epsom salts as a temporary antimigrant until the fixative can be applied from a continuous resin finish formulation.

Also, certain dye classes require oxidation and/or reduction during application and fixing. These dyes (particularly vat and sulfur) were formerly oxidized with dichromate, but are now almost universally oxidized with other materials such as iodate, bromate, or peroxide.

Finally, repair procedures for many classes of dye can involve the use of metals and/or other toxic materials. One type is the zinc sulfoxylate-formaldehyde type of dye stripping agent used on some classes of dyes. This type of repair procedure can contribute to zinc content of waste streams. Another common type of stripping procedure for resin finishes is oxalic acid. This material is known to be toxic. A stripping procedure involving phosphoric acid and urea is equally effective for most resin finishes and with much lower toxicity. The above stripping procedures are for fabric, but one source of toxic stripping agents that is sometimes overlooked is machine cleaners. The cleaning processing frequently are not controlled to the same extent as the dyeing process, and frequently they can contribute to discharge of toxics.

Stripping procedures that are most frequently used in removing unwanted colorant materials from textile materials are:

Stripping Procedures .. 200F unless otherwise stated

1) 2% caustic and 2% hydro, 45 minutes
2) 5+% textone at pH 3.5 for 45 minutes (sodium nitrate helps prevent corrosion of equipment)
3) 3% hypochlorite at pH > 8.5 (or at pH < 5) 30 min, 160F
4) 6% zinc/sulfoxylate/CH_2O and formic acid (pH 4) for 45 min
5) Add 10% dye carrier to any of the above and go to 250F
6) 4% permanganate at pH 3

The use of the zinc sulfoxylate formaldehyde and/or permanganate can produce zinc and manganese in the waste. Also, the use of textone (sodium chlorite) and/or hypochlorite can cause equipment erosion and dissolve metals that compose the machine. The use of hydro and caustic wherever possible should minimize metal contamination of waste streams.

One other management strategy that can frequently be used to reduce the metal content of wastes is the proper handling of metal containing finish mixes. Residual unused portions of finish mixes are usually discarded as waste. Essentially all finish mixes will contain magnesium and/or zinc catalyst, and many special finishes contain other metals.

One abatement reduction is to make up the new chemical finish mixes by adding to the old ones, thus utilizing the formerly wasted materials and saving cost. Also, planning properly so that excessive amounts of chemical mixes are not left over is important. The calculations required for process mix make-up (as opposed to dumping unused portions) can be facilitated by the use of Pearson's Square. This procedure is described in detail in the literature.

4.6 REDUCTION OF CHLORINATED SOLVENTS

This section examines a variety of source reduction options for chlorinated solvents in the textile industry. They also fall into the general categories of chemical substitution, process modification, and improved operating practices and housekeeping measures.

4.6.1 Chemical Substitution

There are a number of chemicals that are technically feasible substitutes for the chlorinated solvents in textile applications, In what follows, these are identified and some of the most important of these substitutes are described. The two classes of substitutes include the low molecular weight organic solvents, and alternative HCFC solvents.

4.6.1.1 Low Molecular Weight Organic Solvents

These solvents include the aliphatic, aromatic and oxygenated compounds. Low molecular weight organic solvents comprise one of the possible categories of substitutes that might be used to replace chlorinated solvents in the scouring process.

Exhibit 4-7 shows some of the low molecular weight solvents currently used in scouring operations. These chemicals can be used as substitutes for chlorinated solvents in scouring conducted at room temperature.

One source reports standard batch processes employing flammable solvents. In one batch process called the Maertens process, flammable solvents are used. Another solvent based process using hexane, white spirits, and isopropanol and water, called the Sover process, is a continuous process.

4.6.1.2 Hydrochlorofluorocarbons (HCFCs)

The CFC producers are investigating a variety of new HCFCs for their solvent properties. These chemicals contain hydrogen which means that they have shorter atmospheric lifetimes than the CFCs, and are thus only minor contributors to ozone depletion.

Exhibit 4-7
Low Molecular Weight Organic Solvents Used for Scouring

Solvent	PEL (ppm)	Flash Point (°C)	Boiling Point (°C)	Latent Heat Evaporation (cal/gm)	Flammable
N-Hexane	50	-21	68.5	80	Y
Kerosene	NA	38-74	175-325	80	Y
Stoddard Solvent	100	38-49	220-300	80	Y
Methanol	200	11	65.5	28.3	Y
Acetone	750	-18	37.1	131.87	Y

NA is not available
Source: Cui, et al, 1988.

HCFC-123 (1,1-dichloro-2,2,2-trifluoroethane). A consortium of CFC producers in the U.S. has organized a toxicity program to test HCFC-123 for chronic toxicity effects. DuPont has recently announced that it will build the first large scale HCFC-123 plant in Maitland, Ontario.

HCFC-123 has a very low ozone depletion potential because it contains hydrogen, it has low photochemical reactivity, good solvent power and stability, low surface tension and it is nonflammable. The chemical has a low boiling point which is advantageous for some applications, but disadvantageous for others. It is likely to be technically appropriate for some cleaning applications. The low boiling point suggests that losses of the chemical would be greater than the other solvents. The HCFC's heat of vaporization and vapor density are higher than those of CFC-113 but lower than those of TCA.

USEPA is currently considering a restriction or ban on TCA because it contributes to ozone depletion. HCFC-123 has an ozone depletion potential of 0.02 compared with CFC-11 which has a defined ozone depletion potential of 1.0. This is much less than TCA's ozone depletion potential of about 0.1.. EPA may ultimately regulate other minor contributors to ozone depletion if they achieve widespread use. The regulatory future of HCFC-123, like other new HCFCs, is therefore in question even before it has been produced.

Although HCFC-123 holds promise as a substitute cleaning agent in the textile industry, it probably will not be available for another three to four years until animal testing is complete. HCFC-123 is expected to be much more expensive than other chlorinated solvents. in spite of these disadvantages, HCFC-123 may be used in new, tighter equipment which reduces solvent emissions dramatically.

HCFC-141b (1,1 -dichloro-1-fluoroethane), like HCFC-123 is not a fully halogenated CFC, although it contains chlorine. HCFC-141b has an atmospheric lifetime that is comparable to that of TCA. Like HCFC-123, HCFC-141b has been exempted as a photochemical smog contributor by EPA. The boiling point is low, which means that it needs to be used in tight equipment.

Some major drawbacks of HCFC-141b are that it is moderately flammable, and is somewhat toxic. Flammability can cause workplace problems and would increase the cost for meeting building codes and equipment needs. HCFC-141b has also been found to be a weak mutagen in short-term tests the CFC producers are now sponsoring chronic tests on the chemical and the results will not be available until 1993. HCFC-141b has an ozone depletion potential of 0.08, almost the same as that of TCA which could mean that EPA may eventually regulate the chemical.

There is an existing commercial production process for HCFC-141b which allows coproduction with HCFC-142b using TCA as a chemical intermediate. The commercial production of HCFC-141b in the U.S. cannot be initiated until the chemical receives sanction under the Toxic Substances Control Act.

HCFC-123 may actually be a better solvent for fabric scouring purposes. Although HCFC-141b will be cheaper than HCFC-123, the latter chemical is not flammable. Furthermore, the lower ozone depletion potential of HCFC-123--0.02 compared with 0.08 for HCFC-141b--may leave it unrestricted for a longer time period.

It is likely that combinations of the two HCFCs will ultimately be used and they may prove suitable for use in the textile industry.

HCFC-225c. This HCFC is a mixture of two different isomers--HCFC-225ca or 1,1,1-trifluoro-2, 2-difluoro-3, 3-dichloropropane. The properties of the isomer mixture are very similar to those of CFC-113. The solvency (KB value) of HCFC-225a and HCFC-225b are 34 and 30 respectively; this can be compared with the solvency of CFC-113 at 31.

HCFC-225c has not yet undergone animal testing and it will be years before results are available. Asahi Glass of Japan plans to build a semi-commercial plant in the summer of 1990.

4.6.2 Process Substitution

4.6.2.1 Scouring Operations

Aqueous Scouring. Aqueous scouring is accomplished in batch or continuous processes, and is similar to the solvent scouring process. Aqueous scouring is currently used in the textile industry to scour fabrics. It employs alkali reagents and anionic or nonionic surfactants to remove the fabric impurities. Alkali compounds commonly used are sodium hydroxide, potassium hydroxide, lithium hydroxide, ammonia and alkali metal alkoxides.

In continuous open-width fabric scouring, the fabric dips into a tank containing detergent and then passes through a pneumatically loaded nip to ensure thorough penetration of the liquor into the fabric. It is then plaited down into a tank containing wash liquor. The fabric sinks through the liquor and is drawn from the bottom of the pile by rollers through opening scroll rolls and a centralizing device onto an endless mesh belt onto which it is held by suction boxes situated under the belt.

While on the belt the fabric is subjected to high pressure sprays of rinsing liquor. The suction boxes draw the rinse liquor through the fabric, removing most before it leaves the belt, at which point the fabric is given a final light pressing.

The substitution of aqueous scouring for solvent scouring necessitates equipment replacement. The equipment to be replaced is dependent on the processes to which the fabric will be subject after scouring. In solvent scouring, the fabric leaves the process dry, while after aqueous scouring the fabric is wet. When the next step in the processing of the fabric is aqueous processing as in the dyeing process, the wet fabric coming from the aqueous scouring machine need not be dried. In this case, the solvent scouring machine would be replaced only by a machine designed for aqueous scouring. However, if the fabric needs to be dry for the next process, as in fabric printing, or if scouring is the last process in the finishing of fabric, which may be the case for yarn dyed goods, then in addition to substituting the aqueous scourer for solvent scouring equipment, a dryer needs to be added.

Aqueous scouring is generally less effective than solvent scouring in removing oils. Aqueous scouring uses alkali reagents to remove oils by the formation of soap with free fatty acids or by decomposition of oils with the formation of soap as part of the reaction. The soap then behaves as an emulsifying agent and removes those substances on which the alkali has no chemical action. Aqueous scouring on the average results in residual oil concentrations of 0.3 to 0.4 percent by weight. Although these levels are higher than those remaining with solvent scouring, aqueous scouring is adequate since a residual oil content under 0.5 percent typically does not pose significant problems. Higher oil concentrations in fabric may make the fabric resistant to dye or print paste. Lower residual oils are beneficial when fabric is heat set. The lower oil residue reduces yellowing and oil "mist" thus helping to maintain occupational standards. Thus, the oil level in a fabric depends on specific operation and is case specific.

Aqueous systems can remove impurities in cotton that solvents cannot, and thus can be used for scouring cotton-synthetic blends, as well as 100 percent synthetics.

Aqueous processing can generally achieve process rates comparable to those of solvents. In cases where drying of aqueous systems would not have an impact on processing time, they can be substituted for solvent systems. In cases where the fabric needs to be dried, this additional step would have an effect on production time.

Aqueous scouring is one of the major sources of wastewater from textile operations. Other wastewater sources are from wool scouring, wool finishing, greige goods mills, woven fabric finishing, knit fabric finishing, carpet mills, stock and yarn dyeing and finishing and specialized finishing. Treatment of wastewater from wool scouring using aqueous system has historically posed problems for the wastewater treatment systems.

A variety of wastewater treatment methods--such as anaerobic digestion and decanter centrifuge, for instance, have been employed. Throughout the world, in the last fifteen years, many wool aqueous operations were converted to solvent scouring operations because of the heavy pollution loading of such operations. Raw wool contains wool grease (wax or lanolin), suint (water soluble material) and dirt (insoluble) that has to be removed during scouring operations. Wool scouring is one of the highest sources of 5-day BOD (BOD_5) in the raw wastewater discharge. The high concentration of mineral dirt and proteinaceous matter in these wastewater streams from wool scouring have led to a high effluent disposal cost. The processes commonly employed to treat these contaminants are sedimentation--either by gravity in a settling tank, or by centrifugal acceleration in a decanter centrifuge--filtration and flotation.

As wool is moved through the aqueous scouring liquor, the possibility of felting is introduced. If alkali agents such as sodium carbonate are used in scouring heavily soiled wool, fiber damage is possible. The use of an aqueous process meant that the water-insoluble wool grease has to be emulsified to remove it from the fiber. The subsequent destabilization of the emulsion to recover grease is difficult.

Solvent scouring has been adopted as an alternative to wool scouring operations to some extent. The Sover process and the Toa process specify use c[illegible]inated solvents for wool scouring. The Toa process uses TCA for scouring of wool fibe[illegible] aqueous scour then removes suint and dirt. The extent to which this process is used is not known.

Emulsion Scouring. This process is another possible substitute for chlorinated solvent scouring. Emulsion scouring is a combination of solvent and aqueous scouring techniques. In emulsion scouring, an organic solvent is dispersed or suspended as fine droplets with the aid of emulsifying agents, which disperse the solvent into water, and coupling agents, which control the size of the droplets. The organic components of the emulsion consist of mineral spirits or a similar petroleum fraction sometimes blended with a chlorinated, aromatic, or naphthenic solvent to improve solvency.

Emulsions have neutral to slightly alkaline pH so are not harmful to metals. Emulsion scouring is sometimes followed by alkaline cleaning to remove the last traces of films. Emulsion cleaners leave a light film residue or oil on the parts. Depending on the specific application, the film residue left by emulsion cleaning may be good for protection and resistance of the fabric.

4.6.2.2 Dyeing Operations

Aqueous Dyeing. Aqueous dyeing processes can replace solvent-based processes, but can also contribute substantially to textile wastewater generation. Color is a visible problem and a high level of dissolved solids is expected. Carriers, which are essential for dyeing polyester, and acetic acid have high BOD. With thermosol dyeing of cotton/polyester blends, carriers may be avoided, thus reducing BOD and COD loads.

Substitution of aqueous dyeing of synthetics would reduce BOD and dissolved solids concentrations but increase the COD of the waste. The wastewater will generally contain 75 to 340 mg/l BOD, 25 to 75 mg/l TSS, 220 to 1,010 mg COD, and have a pH of 7 to 12.

Liquid Ammonia Dyeing. This is a new and patented system which uses anhydrous ammonia to dye textiles and other fibers. It seeks to eliminate the problems of water quality, temperature control, long dyeing cycles, steam for heating dye baths and close pH control. As compared to the aqueous system of dyeing, this system uses liquid ammonia instead of water as a medium to carry dyestuffs to the fiber. Liquid ammonia is an excellent solvent which dissolves the dyestuff and allows it to penetrate into the fiber and fabric. At this point the dye particles have little or no chemical affinity for the fiber at low temperatures. The fiber is then subjected to live steam which drives off the ammonia and leaves the dye chemically entrapped in the fiber.

Due to the low boiling point of liquid ammonia (28 degrees F below zero), the ammonia is driven off very quickly, resulting in extremely short dyeing times. The fiber or fabric is then given a light washing to remove excess dye. This system is said to be adaptable to cellulosic and noncellulosic fibers. It is compatible with 95 percent of existing conventional dyestuffs and has the possibility of eliminating most of the preparation processes for dyeing. The ammonia has also been found to impart a mercerizing and shrinking effect to cellulosic fibers which is very similar to caustic mercerization.

The processing equipment necessary for this system includes a unit for the recovery of ammonia. The ammonia recovery system would mean a large capital investment, but with the increasing cost of all chemical including anhydrous ammonia, it would be essential to include this recovery unit.

This system requires further experimentation and acceptance by the industry but it appears to have more potential for increasing productivity and decreasing the cost of dyes, chemicals and energy than the standard solvent dyeing methods. It appears to be a very promising alternative to use of chlorinated solvents for dyeing.

"Air Lift" Dye System. The traditional system of dyeing , with a few exceptions, uses a basic jet machine. In the air lift system, the fabric is carried through the machine in a jet of air instead of in a jet of water. This necessitates a large blower system but eliminated the need for large water pump. Another major change is that the jet machine has to be made larger since the fabric is relatively dry and bulky instead of floating in a 10 to 1 or 20 to 1 water solution. The method of mixing and applying the dye to the fabric must be altered. The dye is mixed in a foaming chemical and applied onto the fabric in the form of a mist.

In the air lift system, the basic dye cycle for polyesters, wool and other synthetics is as follows:

(1) Application Cycle - The dyestuff is mixed with the foaming chemical and sprayed on the fabric so that a total of approximately 15 percent moisture is applied to the fabric.

(2) Distribution of Dye - Because of the mechanical action of the foaming agent, heat and a frothy foam is created, which allows the dye to distribute evenly throughout the fabric.

(3) Rinse Cycle - The rinsing is performed in the same manner as the application of dye, that is, by injecting a water spray into the air stream rather than using a high volume of water.

The total water consumption in this process is approximately 8 to 10 pounds of water per pound of polyester (one gallon per pound as compared with 40 to 50 pounds of water per pound of polyester (5 to 6 gallons of water per pound) on the regular jet machine. This represents a water reduction in the range of 90 percent at the dyeing operation. Besides eliminating the need for chlorinated solvent in the dyeing process, this method dyeing appears to be very important in reducing water and heat requirements.

Exhibit 4-8 provides a summary of pollution prevention opportunities.

Exhibit 4-8
Summary of Pollution Prevention Opportunities

Pollution Prevention Opportunity/Strategy	**Technique**
General	1) Replace high pollutant process chemicals with others that have less impact on water quality
	2) Use preparation processes which can be performed on continuous and batch equipment - the continuous processes have a greater potential for waste stream reuse
	3) Reuse or conserve materials in the finishing process - reuse residual portions of finish mixes
Pad Batch Dyeing	1) Substitute products in the dyeing processes
	2) Return noncontact cooling water and steam condensates to a hot water holding tank or a clear well
	3) Use adequate mixing and/or metering techniques which maintain good alkali control
	4) Adjust exhaust dye recipes by keeping accurate data of liquor ratios
	5) Employ efficient preparation techniques
	6) Maintain proper temperature control
Water Conservation	1) Use concurrent flow washing or rinsing
	2) Employ simply implemented process modifications
	3) Use low liquor ratio dyeing equipment
	4) Incorporate low add-on finishing techniques
	5) Use rapid inverse dyeing (RID)
	1) Adopt solvent processing technologies - solvents vaporize more easily and can be recovered for reuse
	2) Optimize process and material flow procedures
	3) Use continuous operations instead of batch operations

Pollution Prevention Opportunity/Strategy	**Technique**
Process Changes and New Process Technologies	4) Use circulating baths and rinses
	5) Substitute rope washers for open-width washers
	6) Combine separate operations
	7) Incorporate new textile processing equipment
Chemical Screening/Inventory Control	1) Review toxic chemicals to avoid unnecessary overuse
	2) Ensure quality control of all incoming shipments of dyes and chemicals
Reduction of Metal Waste in Effluent	1) Control metals, organics, acids and alkalines used in the internal distribution system and equipment
	2) Employ proper maintenance and use of alternative structural materials
	3) Select materials with low metal content for specific processing situations
	4) Select appropriate types of oxidizer systems and aftertreatments
	5) Employ repair procedures without the use of metals and/or other toxic materials
	6) Ensure proper handling of metal containing finish mixes
Chlorinated Solvents	1) Substitute chemicals to low molecular weight organic solvents and alternative HCFC solvents
	2) Switch processes to aqueous scouring, emulsion scouring, aqueous dyeing, liquid ammonia dyeing, and the "Air Lift" Dye System

CHAPTER 5
RECYCLE/REUSE/RECOVERY[1]

The previous chapter (Chapter 4) used source reduction technologies such as the use of alternative processes and chemical substitutions.

Source reduction techniques cannot always be accomplished by elimination of chemicals. For example, if cotton is to be prepared properly, alkali must be used. No substitution is possible. In these cases, management strategies must focus on:

- Recycle
- Reuse
- Recovery

Chapter 5 focuses on these pollution prevention technologies.

5.1 WASTE RECOVERY

Recovery systems are used to extract various components of waste streams. Commercial systems include:

- Heat recovery
- Size recovery
- Caustic recovery.

---

[1] This chapter is derived from the following documents:

North Carolina Department of Environment, Health, and Natural Resources, *Identification and Reduction of Pollution Sources in Textile Wet Processing*, by Brent Smith, Department of Textile Chemistry, North Carolina State University: Pollution Prevention Pays Program, 1986.

Source Reduction Research Partnership, *Textiles Manufacture - Source Reduction of Chlorinated Solvents*, prepared for California Department of Toxic Substances Control and the USEPA Office of Research and Development Risk Reduction Engineering Laboratory, June 1991.

United States Environmental Protection Agency, *Development Document for Effluent Limitations Guidelines and Standards for the Textile Mills - Point Source Category*, EPA 440/1-82/022, September 1982.

The easiest systems to adapt to recovery are continuous processes such as mercerization and continuous washing. Wastes from these are usually continuous flow streams of fairly constant characteristics.

Batch processes are not as easily handled. There are techniques to recover heat, for example, from dye waste from becks and other equipment. Examples of recycle/reuse of chemical products are site-specific. Dyebath reuse as well as chemical and heat recovery are discussed in later sections of this report. Several brief examples of recovery/reuse are given here to indicate the type of situations that have application. All are actual mill production situations.

Case I

A manufacturer of delicate lace must dissolve an acetate yarn which has been used to stabilize the lace during processing. He dissolves it in acetone. He then sells the acetone/acetate solution to an acetate producer for regeneration of the acetate and recovery of the acetone. The lace manufacturer gets, in return for his acetate/acetone waste material, clean acetone and acetate fiber. He pays only the cost of the separation process.

Case II

A manufacturer of towels uses a yarn made from a twistless cotton core with a polyvinyl alcohol (PVA) wrapper fiber. The PVA wrapper is dissolved in water after the towel is made, leaving a luxurious twistless yarn on the towel surface. The PVA/water waste product is processed to recover the PVA waste and to regenerate the PVA fiber.

Case III

American Enka Company is a nylon yarn production and research facility. One of their processes uses isopropyl alcohol as a solvent for a fatty amine. The end product is a porous film of polymer. They previously employed an outside firm to distill their waste isopropyl alcohol. They then bought it back for reuse in their production line. Average distillation losses were 15%, but losses as high as 40% had occurred. Also, due to improper cleaning of the distillation column between runs, the isopropyl alcohol returned was often unusable due to contamination with Dowtherm, benzene, ethyl benzene, methyl benzene, various chlorinated hydrocarbons, and other organic constituents. Each batch of recycled isopropyl alcohol had to be analyzed for contamination and, if found unsuitable, required disposal arrangements and fees.

To solve this problem, American Enka purchased a used distillation unit for $7500 and modified it to redistill the isopropyl alcohol in-house. This resulted in a savings of $90,000/year, since it is less expensive to distill the alcohol on-site than to contract these services. In addition, the in-house distillation is more efficient, recovering 90% of the isopropyl alcohol as opposed to the outside firm's efficiency of 85%. Not only does American Enka reuse the pure isopropyl alcohol the distillation unit produces, but they also utilize the still bottoms as an asphalt emulsifier in another product line. The payback period for this project was approximately one month.

One final common example of on-site waste recovery is the recovery of perchloroethylene cleaning solvent by distillation. This reduces the amount of hazardous waste products by a factor of 10 to 100 and saves the cost of using fresh solvent for each dry cleaner load.

5.1.1 Heat Recovery

An excellent review of waste water heat recovery was presented recently [33]. The following summarizes the details of waste water heat recovery systems and their application to textile waste streams. Most textile processors are familiar with waste water heat reclamation systems of some type. The amount of potential or actual dollar savings is often not appreciated, however.

The number of firms that still do not have reclamation systems or let existing ones lie inoperative for long periods of time is surprising. One of the nation's largest textile firms did not start to put waste water heat reclaiming into effect until just recently even though the unsophisticated laundry industry has been reaping its savings for over 30 years.

The Magee Carpet Company installed an 800 GPM reclaim system before 1957. If this 48,000 GPH unit had been in operation for the last 25 years at a conservative 80 hours/week, 50 weeks/year, while raising the incoming average 550°F water to 100°F, at an average cost of U.S. 20¢/gallon for #2 fuel oil for the period, the system would have saved the company a conservative U.S. $3.9 million. This on an approximate $10,000 investment at that time. If they are presently paying 95¢/gal for the fuel, it represents an annual savings of $740,361. In addition, the steam not produced to heat the water is equivalent to more than 700 boiler horsepower.

There are several types of heat recovery system designs that are currently in use.

5.1.1.1 The "Once-Through" Approach

Many systems use a once-through flow of water for heat recovery. Typically, the hot waste water flows to a large sump which has a varying level. The sump pump is usually controlled with level sensors which cycle the system off at a low level. The length of intermittent off periods is determined by the size and periods of dumping inactivity of the becks. The waste water is pumped out of the pit through the reclaimer and then to the sewer. This design has some drawbacks. First, depending upon the flow and temperature of the incoming water to the other side of the heat reclaimer, the exiting waste water may not be "cold". This is especially true if the next scheduled beck dump in the recipe is to be a "cold" one. Just because the waste water has already been through the exchanger does not mean that it no longer contains recoverable BTUs. The once-through concept also assumes that the fresh water flow matches that of the waste water, which does not in fact occur. Next, when there are few or no dumps and the sump level falls to the cut-off point, there obviously is no BTU recovery. Because of the varying level, it is also necessary to position the pump suction at the low point of the sump. This also happens to be the location of the coldest water in the sump. At the cut-off level, the hottest water remains in the pit.

5.1.1.2 Stratified Sump

The stratified sump type system is an improvement based on the fact that heated water will stratify. This allows the sump to release the hottest water available for BTU recovery and to waste the coolest water when excess is present. This is accomplished by a series of underpass and overpass dams. The holding pit is deep and the liquid waste is maintained at the constant level.

When a "cold" dump enters the pit, if it is relatively colder than water presently there, it will sink to the bottom and be the first rejected. If this "cold" dump is warmer than what it encounters, it will float to the top and the BTUs it carries are now available for reclamation.

This establishes a constant level with the hottest water trapped behind the underpass dam and at the top; the system operation can be designed to operate continuously at a fixed flow rate (thus permitting the most economical exchanger selection for good heat transfer). All equipment is based upon this steady average flow consideration, not on a quantity of water in a pit that must be handled before the next dump (at best an assumed value for most plants) on a once-through method. Pump suction is positioned where the hottest water is at the top. During periods of no dumping activity, the system continues to extract BTUs, though obviously not at the same rate. The system thus maximizes heat reclamation regardless of process demand or temperature.

Heat reclamation systems are frequently plagued by plugging due to lint and other sediment that comes from processing of fibrous materials. Therefore, lint screens in dyeing machines, bar grates, and other primary control methods must be maintained to insure proper operation. Also, the design of the reclaimer itself can include anti-fouling features, such as timed backwashes, etc.

Perhaps the easiest streams on which to practice heat reclamation are streams from washers and other continuous equipment. This can frequently be done without the complicated sumps, level controls, and other devices required for batch dumps.

Case I

A case history for heat recovery has been published for Ellen Knitting Mills, which was discharging spent dye bathwater to the municipal sewer system. The temperature of the discharge water was 130°F which caused breakage of the terra cotta sewer piping. In 1981, the company invested $100,000 in a heat exchange system that lowered the effluent water temperature to 70°F. Spent dye water is discharged into a holding vat from which it enters the stainless steel heat exchanger. The exchanger is composed of five 30 ft. long 8 in. diameter pipes. Inside each pipe is a bundle of smaller tubes which allow the heat transfer.

Heat removed from the water is used to preheat incoming feed water for the dye tubs from 55°F to about 105°F. The preheating operation saves about 52,000 gallons of fuel oil per year, and the heat exchange system had a payback period of only two years.

Case II

Russell Corporation improved its conversion efficiency of steam from boilers to hot water for its bleachery by installing back pressure regulating valves to control return line condensate. This reduced the amount of condensate which flashed into steam and returned higher temperature condensate to the boiler. Each 10°F rise of boiler feedwater results savings. The total savings to Russell was $1000 per day.

5.1.2 Size Recovery

Size represents the largest single group of chemicals used in the textile industry, and they do not become a permanent part of the product, in most cases. Therefore, size recovery represents perhaps the greatest opportunity for recovery of any chemical group. This is most convenient in vertically integrated mills where the recovered size can be returned directly to the slashing operation make-up kettles. The common types of sizes used on textile warp yarns are:

Starch	
Carboxymethyl cellulose	(CMC)
Polyvinyl alcohol	(PVOH)
Polyacrylic acid	(PAA)
Polyvinyl acetate	(PVAc)
Polyester	(PET)
Modified cellulose and starches	

By far the most common is starch. It is removed from textile substrates by degradation by the action of acid or enzyme. Because it is degraded, no recovery is possible. The other types are more or less recoverable. The molecular size, water solubility and other factors which influence recoverability are controlled by the molecular structure, particularly the molecular weight and substituents that are added to the polymeric chain. These substituents are used to control adhesion, film forming and penetration properties, removability, and other important features relating to the functional behavior of the size.

The recoverable sizes, primarily PVOH, are more expensive than starch. Thus it is difficult for a nonvertical weaver to use these more expensive sizes so that another independent processor can recover them at a later time. Also, it is difficult for a nonvertical wet processor to buy expensive recovery equipment in hopes that the weaver will use a recoverable size. Therefore, size recovery systems are found typically in vertical operations such as Stevens, Milliken, and Springs.

Typical size recovery scheme is shown in Exhibit 5-1.

5.1.3 Caustic Recovery

The recovery of caustic from mercerizing operations is also practical. Mercerization is the process of treating cotton fabrics and certain blends with concentrated (~ 15% or more) sodium hydroxide solution. Waste streams from this process are extremely alkaline. Because mercerization is always a continuous process, these waste streams are fairly easily handled. Recovery systems can reclaim up to 98% of the caustic used.

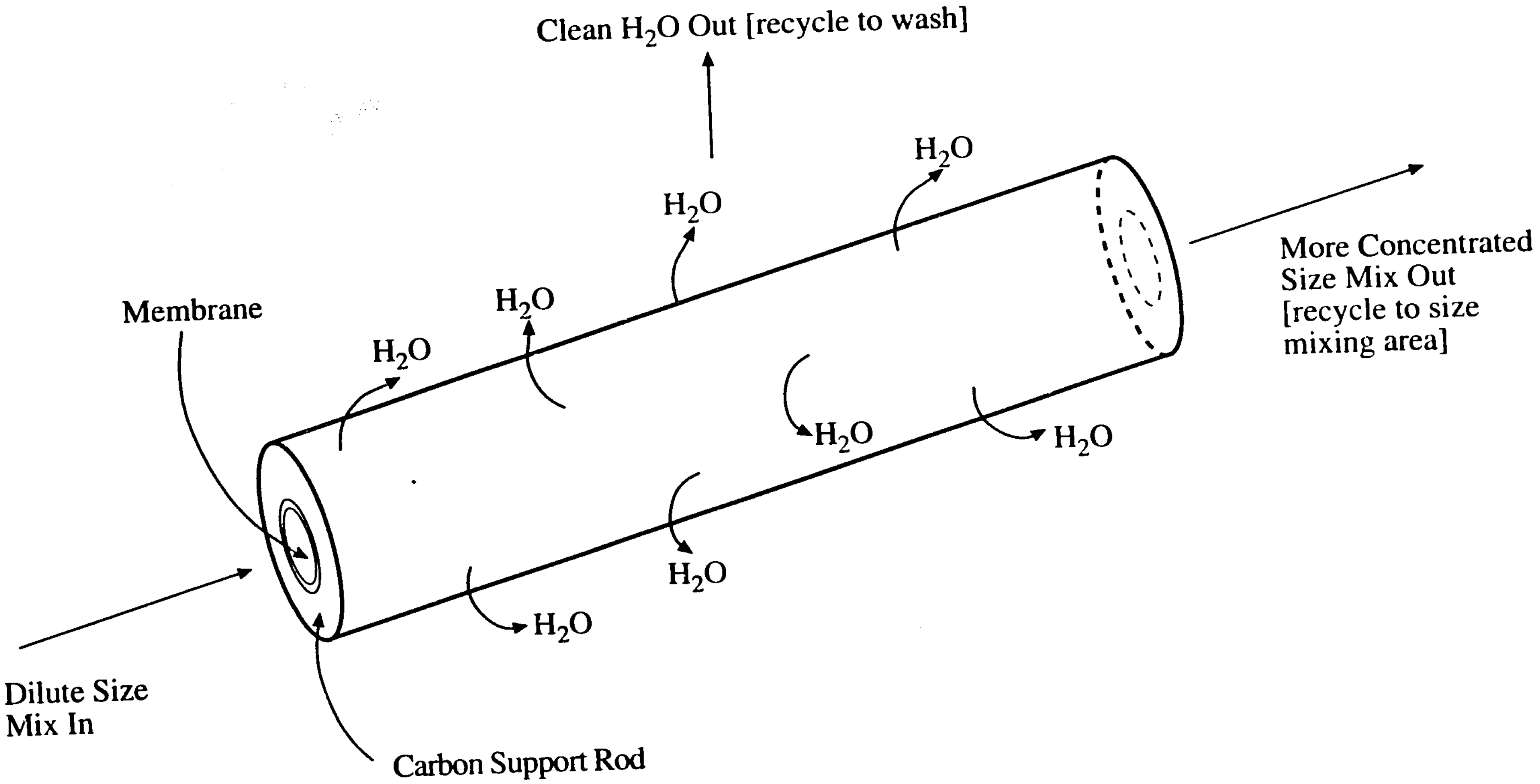
One system that avoids the use of caustic (and also water) in the mercerization process is the use of liquid ammonia. This produces the same effect as mercerization without the highly alkaline waste water stream. Of course, the ammonia gas is recovered and reused.

5.1.4 Water Reuse

Water reuse measures reduce hydraulic loadings to treatment systems by using the same water in more than one process. Water reuse resulting from advanced wastewater treatment (recycle) is not considered an in-plant control, because it does not reduce hydraulic or pollutant loadings on the treatment plant. The two major water reuse measures available to textile mills are: 1) reuse of uncontaminated cooling water in operations requiring hot water, and 2) reuse of process water from one operation in a second, unrelated operation.

Cooling water that does not come in contact with fabric or process chemicals can be collected and reused directly. Examples include condenser cooling water, water from water-cooled bearings, heat-exchanger water, and water recovered from cooling rolls, yarn dryers, pressure dyeing machines, and air compressors. This water can be pumped to hot water storage tanks for reuse in operations such as dyeing, bleaching, rinsing and cleaning where heated water is required. Energy and water savings can be substantial.

Exhibit 5-1
Size Recovery



Reuse of certain process water elsewhere in mill operations also results in significant wastewater discharge reductions. Examples of process water reuse include: reuse of wash water from bleaching operations in caustic washing and scouring; reuse of scouring rinses for desizing or for cleaning printing equipment; and reuse of mercerizing wash water to prepare baths for scouring, bleaching, and wetting fabric.

5.1.5 Dyebath Reuse

The idea of dyebath renovation and reuse began attracting attention around the middle 1970s when energy costs became a critical factor in overall manufacturing costs. Dyebath renovation and reuse has been shown to be an effective method of cost reduction, energy savings, and pollution source reduction in textile wet processing. Laboratory studies, pilot plant work, and full scale commercial use have been documented. This report summarizes these documented studies and presents typical examples of comparative procedures.

In 1964, it was estimated that about 10% to 16% of textile wet processing waste waters in the U.S. were reclaimed or recycled. Modern water and energy conservation practices, including strategies such as dyebath reuse, make possible for wet processors to increase this figure dramatically, with corresponding cost savings and pollution abatement.

Dyebath reuse can be and is an attractive alternative to pretreatment systems for dyehouses that discharge to POTWs. In many cases, dyehouses operating in cities do not have enough space to construct large pretreatment systems. Dyebath reuse, which has been shown to reduce flow, BOD, and COD loadings by up to 33%, requires a smaller investment in equipment than pretreatment systems. Also, the dyebath reuse concept has a return on investment in the form of dye, chemical, and energy savings which pretreatment does not.

Savings that result from dyebath reuse, as well as installation costs and operating expenses, are site-specific. Based on case histories available to date, the data in Exhibit 5-2 generally summarizes the magnitude of these factors.

5.1.5.1 Dyeing Processes - Chemicals, Dyes, etc.

Typically, an exhaust dyebath will contain some or all of the chemical components shown in Exhibit 5-3.

Typically, only the dye and, to a lesser extent, a few specialty products are exhausted during conventional dye processes. Host of the chemicals remain in the dyebath and are discarded with it. Reuse saves the cost and pollution associated with discharge of those chemicals in the spent dye liquors, and it also saves the energy required to heat the dyebath up from the fill water temperature to the appropriate starting temperature for the next dyeing.

Exhibit 5-2
Typical Cost and Savings Figures for Dyebath Reuse per Dye Machine

Lab and support equipment (one set required)	$9,000
Machine modifications, tanks, pumps, pipes	15,000 to 25,000
Annual operating costs	1,000 to 2,000
Annual savings (total)	21,000
Dyes and chemicals	15,000
Water	750
Sewer	750
Energy	4,500

Exhibit 5-3
Components of a Textile Dye Bath

Water

Dyestuff (colorants)

Buffer system/pH control

Electrolyte (common salt or Glauber salt)

Specialty dyeing assistants, such as
- retarder/accelerant
- leveling agent
- defoamer
- surfactant/dispersant
- sequesterant
- other special purpose chemicals

Savings amounts for energy, chemicals, DOD, COD, pH and hydraulic loading of waste streams vary with amounts and types of specialities that are used. These in turn depend on many factors, including the shade being dyed, dye class, color specification (fastness, critical shade match, etc.), equipment, fabric construction and fiber content, and other factors. Some of these will be reviewed in specific cases for each dye class, but some general comments can be made about dyebath components at this time.

Dyestuff (colorant content) is exhausted to a large extent, usually 90 to 95%, onto the fiber. For some dye classes, this involves an approach to equilibrium governed by thermodynamic and kinetic laws without chemical alteration of dyestuff during the process. Establishment of such equilibria is governed by factors such as pH, temperature, liquor ratio, concentration of electrolytes, etc. This is true for acid, basic (cationic), direct, and disperse dyes. In contrast, certain other dye classes undergo chemical reaction during the dyeing process and are therefore conceptually different from the above mechanism. These dyes are typically rendered insoluble, reacted, or entrapped in the fiber in a form that is chemically different from the original form in the dye liquor. Examples are fiber reactive, naphthol (azoic), sulfur, and vat dyes. In such situations, experience with dyebath reuse is not as well documented, although it may be possible to practice dyebath reuse in these cases also.

In any case, dye as it is added to the dyebath is not 100% pure colorant. Commercially, colorants may be cut typically 20% to 80% with various diluents typically which do not exhaust. Because the dye concentrations in the bath are low (typically under 1000 ppm), diluents build up slowly in reused dyebaths over many cycles and are not a severe problem. Diluents vary with dye class, but include surfactants, dispersants, common salt, Glauber salt, soda ash, and other materials that do not usually exhaust.

Buffer systems for pH control include organic acids such as acetic and formic, as well as inorganic salts. Mineral acids are occasionally used. These are usually not depleted except in proportion to the amount that is lost as water is carried off by the substrate (fiber, yarn, fabric). In some cases, where organic acids are used, substantial COD and BOD reductions can be made by dyebath reuse. Alkali systems are typically materials with little or no BOD contribution, such as caustic, soda, ash, TSP, and TSPP, and these can be saved for dyebath reuses.

Electrolytes, primarily common salt and Glauber salt, are typically not exhausted. Although they do not contribute to BOD and COD loads, they can be present at concentrations of over 10,000 ppm in the dyebath for some shades, and can create problems in waste treatment by inhibiting oxygen transfer in aeration, especially under shock loading conditions. Dyebath reuse can save essentially all of these materials except the proportion that is lost with dye liquor that is carried off in the substrate.

Retarders vary greatly in their exhaustion characteristics. Some act almost exclusively on dye in the solution, while others act primarily on the fiber itself. The latter types are essentially 100% exhausted during the dye process. In many cases, separate retarder is not used; rather dye exhaust rate is controlled by pH, temperature, electrolyte concentration and other process variables.

Accelerants, especially dye carriers for disperse dyes on polyester, vary greatly in their exhaust characteristics. These dye carriers typically are blends of organic solvents and surfactants. Components of such mixtures usually exhaust at different rates and can cause an imbalance in the dyebath after many reuse cycles. Also, the components of the carrier-active blend may vary in volatility, causing losses from open dye machines to the air. The BOD loads associated with dye carriers is discussed in the first section of this document.

Leveling agents for disperse dyes on polyester generally exhaust less than carriers discussed above, but are otherwise similar for purposes of this presentation. Leveling agents for other classes (acid, basic, and direct) generally work in the dye liquor and are not exhausted.

Surfactants and dispersants do not usually exhaust. In fact, the concentration of surfactants can be expected to increase with reuse cycles due to the accumulation of unexhausted portions of materials such as dye diluents, retarders, accelerants, levelers, lubricants, and fiber finishes. These may eventually cause significant changes in dye exhaust rate, retarding of dyeing, and lower ultimate exhaustion of dyebath if allowed to build up too much. It is impurities like this that limit the number of time as a dyebath can be reused. The number of reuse cycles varies for each specific dye/fiber situation; however, in general, most dyebaths can be reused at least 5 to 10 times, and few can be reused more than 20 to 25 times in commercial situations.

Lubricants such as mixtures of surfactants and other materials (like butyl stearate) typically exhaust and must be at least partially replaced for dyebath reuse as part of the renovation procedure.

Defoamers, sequesterants, and other specialities are used on as-needed basis in small amounts, and are not generally lost.

5.1.5.2 Methods

1. *Store the spent dyebath* in a tank or in a second identical dyeing machine. One interesting application of dyebath reuse involves moving the dyebath back and forth between two or more machines. For example, package dyeing machine "A" can be preparing yarn while a second identical machine "B" is in dye. When B completes its dye cycle, the bath is pumped to A for renovation and dyeing. In the meantime, the yarn in B is afterscoured, unloaded, and

104

a new batch is loaded and prescoured. By that time, A has finished dyeing, and the bath goes back to B for another reuse cycle.

2. *Analyze or estimate the dye and chemical content of spent dye liquor* the using a spectrophotometer and/or guidelines based on specific production experience. Equipment for this is commonly available at a cost of under $10,000 (See Exhibit 5-4).

Unexhausted dyestuff is measured by solution coloristic techniques, sometimes using extraction techniques if the bath is turbid. Extraction solvents include 1-octanol for basic and acid dyes and toluene for disperse dyes.

Chemical losses are determined by specific production experience based on losses due to exhaust, volatilization, and dye liquor carry-off with the dyed substrate (usually about 10 to 15%).

Exhibit 5-4
Dyebath Analysis Equipment

Equipment Required	**Quantity**	**Source**	**Catalog Number**
25 ml graduated cylinder	2	(1)	08-550C
25 ml sample (separatory) funnels	2	(1)	10-437-10C
20 cc glass syringe	2	(1)	14-823-10D
Ring stand and rings	1	(1)	14-670C, 14-052B, and 05-738
Cotton stand and rings	1	(1)	--
Table salt	1 pound	--	--
Solvent	4 liters	(1)·	--
Sample cells	4	(1)	14,385-912B

(1) Fisher Scientific Company, Atlanta, Georgia (404) 449-5050
Approximate cost (1983) $350

Chemical losses may be estimated or determined analytically if appropriate equipment is available. Usually the quantities are not as critical as the dye, and an estimate is sufficient.

The procedure for extracting dye from the dyebath is as follows:

1) Add 20 ml (25 grams) of salt, 25 ml of exhausted dyebath, and 25 ml of solvent such as 1-octanol or toluene in succession into a clean separatory funnel.

2) Place stopper in funnel and shake vigorously for 30 seconds. Allow contents to separate for 30 seconds. Shake vigorously again for 30 seconds. (This mixing action results in extraction of dyes from the dyebath water into the solvent.)

3) Place funnel on ring stand and allow for distinct separation of salt (bottom layer), water (middle layer), and solvent with dyes (top layer). Solvent layer may appear cloudy due to water in the solvent.

4) Remove stopper. Open the stopcock and allow the salt and water layers to drain out to sink. Close stopcock.

5) Place two cotton balls in clean, dry syringe. Drain solvent layer from funnel into syringe.

6) Allow solvent to pass through cotton balls in syringe to absorb any remaining water, and collect sample in a clean, dry sample cell as it leaves the syringe.

3. *Add make-up amounts of dyes and chemicals* to renovate the spent bath. Also add water to make up the volume that is carried off by the dyed substrate.

4. *Reuse the bath for another dyeing.* Because the used dyebath will usually be hot (over 140°F), it must be cooled down to an appropriate temperature for starting the next dyeing. Considerable time and energy are saved by starting the next dyeing at the highest possible temperature consistent with desired quality factors. This is one of the main advantages of dyebath reuse. The ultimate "life" of a dyebath varies according to the quality required, contaminant buildup, and other factors.

5.1.5.3 Dye Classes and Potential for Bath Reuse

There are many different classes of textile dyes, and each class applies to specific fiber types and requires different exhaustion procedures, specialty, chemicals, pH, equipment, etc. Because of these differences, the savings that can be expected vary. Also, results may vary in respect to the fastness, shade reproducibility, and other factors. Batch dye systems that have been reported to be adaptable to dyebath reuse are shown in Exhibit 5-5.

Specific case histories are cited for several dye/fiber classes, including acid/nylon, basic (cationic)/ Nomex, and disperse/nylon under case histories.

Exhibit 5-5
Systems for Dyebath Reuse

Produce	Fiber	Dye class(es)	Machine
Knit fabric	Polyester	Disperse	Jet
	Cotton	Reactive or direct	Beck
	Poly/cotton	Disperse/reactive or direct	Beck
Yarn package	Polyester	Disperse	Package
	Poly/cotton	Disperse/reactive or direct	Package
Socks	Nylon/spandex	Acid	Paddle
Pantyhose	Nylon/spandex	Disperse/acid	Rotary drum
Carpet	Nylon	Disperse/acid	Beck
	Polyester	Disperse	Beck
Woven fabric	Aramid	Basic	Jet
Skein	Acrylic	Basic	Skein

No case history has been published for direct dyes on cellulose; however, this could also be done. This would result in chemical savings of salt, leveler/retardant, dye, surfactant, lubricant, and defoamer. Dyebath reuse would likely be limited by contaminant buildup of two types.

1. Fabric impurities not removed during preparation
2. Emulsifier systems wetters and dispersants from dye, retarder, etc. These should be of fairly minor importance, and dye reuse should be possible for 15 or more cycles.

A laboratory study of reuse of disperse dyes on 100% polyester spun yarn (package dye) showed that nine reuse cycles could be expected, with savings of about 808 on water and chemicals, and about 40% on energy.

5.1.5.4 Limitations

To gain the maximum benefit from dyebath reuse, users must keep certain considerations in mind.

The easiest systems to manage for dyebath reuse are dye classes that undergo minimum chemical changes during the dyeing processes. These are:

1. acid dyes for nylon and wool
2. basic dyes for acrylic and certain copolymers
3. direct dyes for cotton
4. disperse dyes for synthetic polymers.

A higher degree of difficulty can be expected from other classes.

The easiest situation to manage is the reuse of a dyebath to repeat the same shade with the same dyes and equipment on the same fiber. It is also possible to reuse a dyebath to produce a darker or lighter shade with the same dyestuff selection on the same fiber. More difficult situations would involve addition of new colorants to renovate a dyebath. This would lead to potential problems with shade matching and metamerism.

The number of cycles that a dyebath can be reused is limited by buildup of impurities. These impurities can come from several sources. One source is fabric impurities from incomplete preparation, which include natural impurities in cotton and wool, knitting oils, winding waxes and emulsions, fiber finishes, size materials and the like. Impurities can also accumulate from dye diluents, salt buildup from addition of acids and bases for pH control, steam impurities for direct steam heated baths, and emulsifier systems from exhausted specialties. Many impurities are surfactants, and these can cause stripping and/or retarding of dye exhaust if allowed to buildup excessively. Other problems such as spotting and excessive foaming can occur if too many reuse cycles are attempted. The usual range of reuse cycles is 5 to 25, and each process and/or shade must be optimized by actual production experience.

Specialty dye assistants and other materials that are essential to the dyeing process may be lost by several mechanisms. These include losses due to vaporization from open dyeing machines, exhaust onto the fabric, chemical reaction, and dye liquor carry-off by the substrate. These losses may vary from 10% upward and may vary between components of a blended chemical specialty. To assure best results, dyeing assistants must be carefully screened for reuse performance.

One major reason for using bath (exhaust) dyeing is the ability to produce small lots, short runs, and fast turnaround times. Because dyebath reuse requires special scheduling considerations, it may limit somewhat the flexibility of bath dyeing operations.

In summary, batch dyebath reuse may not be for every situation; however, the economic savings are large, if properly applied.

5.1.5.5 Examples

Case I

Perhaps the most extensive and best documented study on dyebath reuse was carpet dyeing done by Bigelow in the summer of 1983. In this work, carpets were dyed with conventional (Exhibit 5-6) and with dyebath reuse (Exhibit 5-7). Results of quality, savings, and pollution abatement were carefully documented in detail. Some of the more interesting data relating to pollution abatement show that BOD and COD were reduced by over 30%, and phosphorous, phenolics, and total dissolved solids were reduced by 50% and 80% (see Exhibit 5-8).

Dyeings in Bigelow production runs were done on two different shades and styles of carpet. A pair of conventional atmospheric becks were used, and dyebath was pumped back and forth between them. Over twenty reuse cycles occurred. Savings were estimated to be over $60,000 per year per pair of becks.

Case II

Adams-Millis company has practical dyebath reuse in plants at High Point and at Franklinton, NC. In both cases, nylon pantyhose were dyed in rotary paddle machines with disperse dyes. The results were so good that 95% of the rotary drum machines at the Franklin plant are reportedly running dyebath reuse systems. The idea of reuse was also used in these operations in another way.

The final softener bath is reused as a prescour for the next batch to remove oils, fiber finish, etc., before dyeing. Cost savings are estimated at 2¢/lb of goods produced. Conventional and reuse procedures are shown (Exhibit 5-9 through 5-11).

Case III

Evans & Black (E&B) Carpets instituted dyebath reuse at its Dalton, GA, plant for the disperse dyeing of nylon carpets. The result was a projected savings of $115,000 annually to the mill using eleven becks.

At this time, 45% of the plant's production is dyed with reused baths. It was confirmed in this production situation that buildup of surfactants during the repeated reuse cycles causes slight decreases in the disperse dye exhaust. This is only a minor problem and can be compensated in general by increasing the dye concentrations slightly as reuse cycles increase.

Exhibit 5-6

Conventional Carpet Dye Procedure

---

1. With beck drain closed, load carpet into beck using spray to assist in moving carpet over reel.
2. Fill beck with cold water.
3. Add auxiliary chemicals to the beck; continue mixing for five minutes after all chemicals have been added.
4. Measure pH and adjust if necessary.
5. Add dyes and mix for 10 minutes.
6. Raise dyebath temperature to 180°F at 3°F per minute.
7. Dye at 180°F for 30 minutes.
8. Patch and, if necessary to obtain acceptable dyeing, perform adds(s). (After each add, dyeing is performed for 15 additional minutes.)
9. Add cold water with beck drain open to cool to 150°F or lower. Shut off water and drain beck.
10. Close drain and fill beck cold water to rinse, cool, and float carpet.
11. Drain and flush beck to prepare it for next dyeing.

Exhibit 5-7
Modified Procedure for Carpet with Dyebath

---

1. With beck drain open, load two rolls of carpet onto beck using spray rinse (tint added to greige carpet is removed from carpet yarns during spray rinse; for reconstituted dyeings, the drain is left open to prevent tint buildup in recycled dyebaths).

2. Close drain. Arrange and connect dyebath transfer equipment into appropriate orientation. Set flowmeter totalizer to zero. Pump dyebath to new beck from beck used for previous dyeing.

3. Add auxiliary chemicals to beck; continue mixing for five minutes after all chemicals have been used.

4. Measure pH and adjust if necessary.

5. Add dyes and mix for ten minutes.

6. Raise dyebath temperature to 180°F at 3°F per minute.

7. Dye at 180°F for 30 minutes.

8. Sample and, if necessary to obtain acceptable dyeing, perform add(s). (After each add, run 15 additional minutes.)

9. Add cold water with beck drain closed and cool to approximately 140°F. (Some exhausted dyebath will be lost through overflow ports.) Collect dyebath sample for absorbance measurement. Pump to new beck (Step 2 of subsequent dyeing cycle). Perform solvent extraction of dyebath sample, perform absorbance measurements and calculate amount of dyes and auxiliary chemicals required for next dyeing. Drain.

10. Close drain and fill beck, cold water to rinse, cool, and float carpet.

11. Unload carpet. Drain and flush beck to prepare for next dyeing.

Exhibit 5-8
Pollution Reduction Results
Dyebath Reuse for Carpet

Pollutant	Conventional	Pollutant Loading Carpet Style I Dyebath Reuse	Reduction
BOD (g/kg)	23	15	35%
COD (g/kg)	56	39	30%
TSS (g/kg)	0.53	0.26	51%
TDS (g/kg)	31	14	55%
Phenolics (mg/kg)	1.5	0.8	47%
Total-P (g/kg)	2.8	1.0	64%

Pollutant	Conventional	Pollutant Loading Carpet Style I Dyebath Reuse	Reduction
Pollutant			
BOD (g/kg)	22	14	36%
COD (g/kg)	80	54	32%
TSS (g/kg)	0.2	0.14	30%
TDS (g/kg)	40	21	48%
Phenolics (mg/kg)	0.8	0.15	81%
Total-P (g/kg)	1.9	0.5	74%

Exhibit 5-9
Disperse Nylon
Conventional Adams-Millis Procedure for Dyeing

Step

1. Fill with cold water.
2. Add auxiliary chemicals, run 3 minutes.
3. Raise temperature as rapidly as possible to 160F.
4. Add disperse dyes, start basket turning.
5. Run machine 2 minutes.
6. Load goods evenly while turning machine downward into bath.
7. Run 45 minutes at 160F.
8. Sample; make add if necessary.
9. Dump the bath.
10. Refill with cold water.
11. Inject steam rapidly to reach 110F.
12. Add finish chemical and run 10 minutes at 110F.
13. Dump the bath.
14. Unload the pantyhose.

Approximate running time (zero adds) = 1 hour 40 minutes (100 minutes)

Exhibit 5-10
Disperse Nylon
Reuse Procedure With Prescour for 5-cycle and 17-cycle Sequences

---

Step

1. Load goods evenly to machine full of softener water from previous cycle.
2. Run for 5 minutes.
3. Drop prescour bath to drain.
4. Unload wet hose from machine.
5. Drop dyebath into machine (130-140 gallons).
6. Add water until 160 gallons reach on sight glass.
7. Raise temperature as rapidly as possible to 160F with rotation.
8. Add auxiliary chemicals.
9. Add dispersed dyes.
10. Run 2 minutes.
11. Reload goods evenly while turning downward.
12. Run 45 minutes.
13. Sample; make add if necessary.
14. Sample dyebath for analysis.
15. Pump dyebath to holding tank and drain residual water in machine.
16. Add 160 gallons water (fill to 200 gallons on sight glass).
17. Raise to 110F.
18. Add finish chemical.
19. Run 10 minutes.
20. Unload goods.
21. Return to Step 1.

Exhibit 5-11
Disperse Nylon
Reuse Procedure Without Prescour for 14-cycle and 17-cycle Sequences

---

Step

1. Drop dyebath into machine (130-140 gallons).
2. Drain side pipe.
3. Add make-up water to 190 gallons on sight glass.
4. Add steam to 160F.
5. Add auxiliary chemicals.
6. Add disperse dyes (plus 3 gallons water).
7. Load goods (dry).
8. Run 45 minutes at 160F.
9. Sample; make add if necessary.
10. Sample dyebath for analysis.
11. Pump dyebath to holding tank.
12. Add 160 gallons of fresh water (to 200 gallons on sight glass).
13. Raise to 110F.
14. Add finish chemical (plus 3 gallons water).
15. Run 10 minutes.
16. Drain softener bath.
17. Unload goods.
18. Return to Step 1.

Case IV

Basic dyes are normally exhausted from acidic baths for acrylic and certain other copolymer materials. One case history relating to dyeing basic dyes on Nomex in jet dyeing machines is available. Traditional and reuse procedures for Nomex dyeing is provided in Exhibits 5-12 and 13.

In these evaluation trials, dyebaths were reused up to 15 times successfully. Capital expenses to install the equipment necessary to accomplish dyebath reuse were determined to be about $15,000. Savings were estimated to be $120 to $140 per dye cycle (500-700 lbs) for a cost reduction of 17 to 28¢ per pound. The annual savings to the mill was estimated at $100,000.

In this data, like the Adams-Millis study, there was uneven depletion of various components of dye carrier during the dye process. This required a reconstitution of 65% for dye carrier compared to 10% for other chemicals.

Case V

Acid dyeing of nylon carpet using reconstituted dyebaths was done on atmospheric becks. Dyebath reuse was limited to 10 cycles due to buildup of salt. This led to an annual savings estimated at $31,300 compared to a total cost of $15,000 for installation of necessary equipment.

5.1.6 Recovery and Reuse of Vapors

Recovery and reuse technologies for chlorinated solvent vapors have been available and practiced or years in the textile industry. Several of these techniques are examined that are used today or that are promising for use in the future by the textile industry. These include carbon adsorption, polymeric adsorption, the Brayton Cycle Heat Pump and the membrane separation system.

5.1.6.1 Carbon Adsorbtion

This technology can be used to recover various chlorinated solvents from a vapor waste stream. The solvent vapor and air stream can be channeled to a carbon adsorption unit for recovery. Higher exhaust velocities do not necessarily result in increased recovery of the material. the higher airflow draws more solvent vapor and can result in disruption of the air/vapor interface causing an increase in emissions. Carbon adsorption systems may be most appropriate for use on large scouring units where the credit form solvent recovery helps to offset the high capital equipment cost.

In the adsorption step, the solvent is adsorbed using activated charcoal. The desorption step is generally accomplished with steam. For desorption, the bed is initially heated with steam for 5 to 15 minutes, and then the solvent vapors leave the bed and are routed to the condenser. The solvent and the water phases are then separated by gravity or by distillation.

Proper operation and maintenance procedures are critical to maintain the efficiency of the carbon bed. Examples of operating procedures that have an effect on the operation of carbon bed are: 1) dampers which do not open and close properly to allow the solvent vapor/airstream to pass the bed, 2) use of carbon that does not meet the specifications, and 3) improper timing of the desorption cycles. Desorption cycles must be frequent enough to prevent breakthrough of the bed, but no so frequent to cause excessive energy consumption.

PERC, TCE and CFC-113 can be recovered using carbon adsorption, but TCA requires special equipment. For TCE and PERC, carbon adsorption equipment is normally constructed of mill steal covered with a solvent-resistant coating. TCA is very susceptible to hydrolysis. Consequently, its recovery equipment is often constructed of Hastelloy C and can cost much more than coated mild steel absorbers.

Carbon adsorption subjects the recovered solvent to water. This removes the water soluble components, and the recovered solvent may not be directly suitable for recycle and reuse. In the case of TCA, for example, contact with water condensate will remove water soluble stabilizers and the new unstable TCA may decompose and form HC1 which can easily corrode equipment. Water pollution problems also may result from the materials dissolved in the discarded water. Indeed, water soluble stabilizers removed during steam desorption will end up in water, and eventually enter the sewer system. For this reason, it may be necessary to use special construction material such as Hastelloy which raises the cost of carbon adsorption even higher. Some chlorinated solvent may also remain in the steam condensate but the residuals are very small.

The carbon used in the carbon adsorber bed must be periodically discarded. Although carbon regeneration is practiced either on-site or off-site, it is recommended that the carbon be completely replaced every 10 to 15 years.

5.1.6.2 Polymeric Adsorption (PA)

PA is a new process developed by Nobel Industries in Sweden, for solvent recovery and purification. The process is based on the adsorption of solvent on macroporous polymer particles, using a fluidized bed technology. Specially developed polymers have been optimized for use as absorbents; they consist of cross linked polymer particles of styrene divinyl benzene, with an average pore diameter of 80A, and a surface area of about 8600 ft^2 /gr. The diameter of the polymer particles is about 0.02 inches and the specific weight is about 18 pounds/ft^3. The polymer adsorbent has several advantages according to the manufacturer. First, it is easy to regenerate. Second, it has a long life time, and third, it has no catalytic effect on the degradation of unstable solvents. It is therefore suitable for use with TCA.

The adsorption capacity of the solvents is strongly dependent on the boiling point; the lower the boiling point, the lower the adsorption capacity. Thus it has good potential for use with CFC-113 which has a boiling point of 117 degrees F.

The solvent is adsorbed by the polymer particles as the air passes through the adsorption beds. The flow of air also causes the polymer adsorber to fluidize, and behave like a liquid. A continuous flow of adsorbent through the bed is maintained as the saturated adsorbent is removed from the bottom and regenerated and simultaneously fed at the top of the adsorption section. Absorbent is then heated to a suitable temperature in the desorber, the released solvent is picked up by stripping air, and the released solvent and air are collected and routed to the condenser. This process continues indefinitely. The process is attractive because it has fewer moving parts and lower energy consumption.

According to the manufacturer, the PA process is specially suited for continuous emission airflows from about 300 scfm to 100,000 scfm and for solvent concentration between 0.005 and 0.1 pounds/1,000 cubic feet. It is especially favorable for humid air, for water soluble solvent, or ones that oxidize in warm humid air. This process is also recommended for solvents with low boiling points (<105 degrees F); however, the incoming temperature should be kept below 90 degrees F. Presently, a pilot test unit and a full scale AB plant are operating in Sweden.

5.1.6.3 Brayton Cycle Heat Pump

The Department of Energy (DOE) has been supporting the development of the BCHP in conjunction with 3M and Garrett Air Research since 1978. The technique uses a reverse Brayton refrigeration cycle to condense solvents to liquids. It cools gas streams to very low temperatures--commonly -298 degrees F--and condenses the components for collection.

Another regeneration technique has been developed that requires the use of inert gas in combination with BCHP and allows direct reuse of the solvent in the process. The activated carbon adsorbent catalyzed a reaction that produces unwanted by-products and also releases heat which has led to carbon fires. The BCHP eliminated the need for distillation by eliminating water and uses special absorbents which minimize catalytic reaction. The system is identical to a conventional adsorption system during the absorption cycle. The organic materials are then regenerated using the BCHP process. Hot, inert gas passes through the adsorbent bed and desorbs the adsorbed material. The solvent laden inert gas is cooled, compressed, cooled further and sent through the compressor side of a free-spindle turbo unit.

It is further cooled in an interchanger and enters the expander side where it is cooled to as low as -80F.

To prevent ice formation, water must be eliminated from the regeneration gas. Use of either drying steps or appropriate water rejecting absorbents can eliminate the problem. BCHP eliminates the use of steam for regeneration of adsorbents. Because it operates in low pressure vessels. the capital and operating costs of the BCHP are substantially lower than for other systems, according to the manufacturer. This method has been demonstrated at 3M for solvent recovery on commercial sized magnetic tape manufacturing facilities (Nucon, 1989). But it has never been demonstrated in other facilities for the recovery of chlorinated solvents.

There are two thermodynamic advantages to the BCHP method. First, in the Brayton cycle, an increased pressure is used. The dew point temperature of a substance in the gas stream increases as the gas pressure increases. This cycle operates more efficiently than other system which condense the components at atmospheric pressure. Second, the Brayton cycle employs a turboexpander where most of the work input to the compressor stages is recovered.

5.1.6.4 Membrane Separation System

Another new system is being proposed to collect vapors from air streams. Synthetic membranes have recently been used to separate aqueous and gas mixtures, and for recovery of hydrogen from petrochemical purge gas streams and other chemical production processes. Since membranes can be tailored to fit a certain mass separation task, they seem to be appropriate for separation problems which are difficult to handle, such as removal of organic solvent from waste air streams. A semipermeable composite membrane is used to separate the organic solvent from air. The membrane modules, which are composite structures made by coating a tough relatively open microporous support membrane with a very thin, dense film, allow a large membrane surface area to be packed into a small volume. The support membrane provides mechanical strength and the thin dense coating performs the separation. Organic solvents are preferentially drawn through membrane by a vacuum pump and the solvent is condensed and removed as a liquid.

The firm manufacturing the membranes claims that comparison with carbon adsorption shows that the membrane process is more cost-effective if the solvent concentration is relatively high--0.5 percent or higher--and the airstream to be treated is small--between about 100 and 1,000 standard cubic feet per minute. It should be noted that the membrane systems do not generate secondary waste streams like carbon adsorption units. Capital costs of the system are in the range of $400 to $1,000 per standard cubic feet per minute (scfm) of airflow with an operating cost of $0.5 to $1.00 per 1,000 scfm treated.

5.1.6.5 Housekeeping Measures

A variety of different practices adopted on-site can minimize solvent losses. Proper procedures to start-up/shutdown the solvent scouring machine include starting the condenser coolant flow prior to turning on the sump heater and keeping it on after the sump heater is turned off.

Losses during transfer of solvent into and out of the scoring machine can be minimized if solvent filling, draining, and transfer are performed with enclosed piping systems. Pumping the solvent directly from the drum to the scouring machine could cut down on spills and diffusional losses. If the solvent is pumped into the scouring machine with little or no splashing, such as with submerged fill piping, less solvent would be lost. Leakproof couples can also reduce transfer losses. Emission monitoring can commonly lead to helpful information to evaluate plant practices.

Finally, other measures such as good planning and inventory control, repair of visible leaks and conduct routine equipment inspections, can lead to reduction in solvent use.

5.2 WASTE REUSE FROM OFF-SITE SOURCES

The idea of reusing can be extended beyond in-house reuse. For example, a waste stream that commonly is produced from pickling of agricultural products is 17% acetic acid. This product has been filtered and used in textile dyeing to provide the required acidity in disperse dye baths. Usually, the mill would use 56% acetic acid, so the dye recipe must be adjusted to use about three times as much of the 17% acetic acid.

Textile manufacturers located close to furniture mills can frequently obtain large quantities of wood scraps for their boilers. This eliminates wood scrap waste from furniture mills and it saves fuel cost for the textile mill.

In another case, Eileen Mills was able to purchase and install a sawdust-fired steam generating plant for approximately $800,000. The unit consists of a 12 ton receiving hopper, a conveyor transport system, a hogger, a 200 ton storage silo, a dutch oven combustion chamber, an auxiliary oil burner, and a 400 horsepower HRT boiler.

Exhibit 5-12
Traditional Dyeing Procedure for Nomex Type 455

Step

Dyeing

1. Fill dyeing machine.
2. Load fabric.
3. Add to bath at 10F (38C):
   1% surface active agent (Merpol HCS)
   20 g/l. carrier (Dymex)
4. Run 5 minutes.
5. Add cationic dyes which have been pasted with acetic acid and dissolved in water.
6. Run 5 minutes.
7. Add in three parts over 20 minutes, 20 g/l. sodium nitrate.
8. Adjust pH to 3.5 to 4.0 with either TSPP or acetic acid as required.
9. Raise to 250 F (121C) at 3F (1.7C)/minute.
10. Run 1 hour at 250F (121C).
11. Cool to 150F (66C) and sample; dye adds should be run at least 1 hour at 250F (121C) to insure penetration.
12. Cool to 120F (49C) and drop bath.
13. Rinse clear at 120F to 130F (49-54C).

Exhibit 5-13

Modified Dyeing Procedure for Nomex Type 455 for Dyebath Reuse

---

Step

Dyeing

1. Fill dyeing machine with reconstituted bath.
2. Load fabric.
3. Adjust pH to 3.5 to 4.0 with either TSPP or acetic acid as required.
4. Raise to 250F (121C at 3F (1.7C/minute))
5. Run 1 hour at 250F (121C).
6. Cool to 150F (66C) and sample; dye adds should be run at least 1 hour at 250F (121C) to insure penetration.
7. Cool to 120F (49C) and pump bath to holding tank.
8. Rinse clear at 120F to 130F (49-54C).

In the vicinity of Spruce Pine, NC, there are several local saw mills and a ready supply of waste sawdust. The sawdust is trucked to the mill, where it is dumped into the receiving hopper, passed by conveyor belt under a magnet to remove metals, and onto a hogger where it is ground to a uniform size. The sawdust is then lifted by a bucket elevator to the top of the storage silo, which holds an 8-day supply of fuel.

Sawdust exits the silo from the bottom, where it is collected in a metering bin which dispenses it to a screw conveyor leading to the boiler. The metering bin has sensing devices to monitor the steam pressure in the boiler and releases sawdust as needed to maintain a constant pressure. The measured charge of sawdust is blown into the dutch oven where combustion takes place. The heat produced by this combustion is introduced into the boiler where the steam is generated.

The exhaust gases pass through a series of cyclone separators to remove any particles and then into a smoke stack. At this point a heat exchanger transfers heat from the exhaust and reinjects it under the grate in the combustion chamber. Since the mill has ample capacity in their dyehouse heat exchanger, they are using the preheated water as their boiler make-up water. This results in greater energy efficiency for the system.

The new boiler system has eliminated the need for 300,000 gal/yr of fuel oil. The sawdust fuel costs approximately $12.00/ton; the company reports a 66% savings on fuel costs. They estimate a payback period of only four years for the new system. The new boiler is also a much cleaner system since it is equipped with state-of-the-art pollution control devices. Cyclone separators scrub the vapors and prevent the particulate "fallout" that was present with the oil-fired steam generator.

Another common waste reuse practice is the sale of rags, seam waste, and selvage trimmings, which are sold to craft supply stores and rug manufacturers. Then wastes, especially selvage trimmings from knit goods, can be sold at a profit and the solid waste from such sources is thereby eliminated.

5.3 RECYCLING OF WASTE SOLVENT

There are several methods of reducing the use of virgin chlorinated solvent by recycling contaminated liquid solvent. A number of methods for treating contaminated solvent so that it can be reused are discussed. The techniques evaluated are on-site recycling and off-site recycling.

5.3.1 On-Site Recycling

Solvent reclamation is one of the most common methods of handling waste solvents on-site. All solvent scouring machines are commonly designed with a distillation system in place. On-site recycling has become attractive because of the high cost of virgin solvent, especially for expensive solvents like CFC-113. The use of on-site stills to recover solvent can result in up to a 20 percent reduction in solvent use.

Chlorinated solvent reclamation is technically feasible because of the stability of most chlorinated solvents and their relatively low boiling points. There are many on-site reclamation techniques that can be employed to reduce solvent use, including single plate distillation, aqueous extraction, sludge or nonvolatile residue removal, and fractional distillation. The most common of these are evaluated below.

On-site distillation equipment falls into three categories: 1) process stills, 2) on-site solvent recovery stills and 3) semiportable ministills. Process stills are used in conjunction with scouring machines. Dirty solvent from the sump of the scouring tank is pumped to the still for distillation, then returned to the tank. Continuous distillation, which allows continuous cleanup of contaminated solvent, does not require the unit to shut down as often as required without use of the still. Batch distillation is performed when enough volume of spent solvent is accumulated. The spent solvent is then pumped into the still, distilled and put back in drums or storage tanks.

Single plate distillation, illustrated in Exhibit 5-14, is the most commonly employed method of recovering solvent; it involves boiling and vaporizing the solvent. The lowest boiling materials distill first and then the high boiling constituents come off. The higher boiling impurities and sludge remain at the bottom of the still. In-house distillation is appropriate for pure solvents and for azeotropes; it is less appropriate for blends or formulations with stabilizers because the solvent must be reformulated before reuse. Stills can be steam-heated, electrically-heated or gas-fired. Still bottoms that result from the distillation process can contain up to 50% solvent; they can be processed further by using steam stripping or thin film evaporation to recover even more solvent. They can also be sent to off-site recyclers (see below) who will reclaim additional solvent.

Repeated single stage distillation can be used to separate close boiling solvents such as CFC-113 (with a boiling point of 117°F) and TCE (with a boiling point of 189°F). Multistage or fractional distillation is accomplished by providing vapor/liquid contact by using column trays or packing.

Another possible method of reducing the amounts of waste being shipped off-site is use of a mobile on-site solvent reclaimer. This service is offered by Solvent Processors and Reclaimers Corporation (SPaR) of Fairfield, Ohio. Mobile on-site recycling is simply a solvent distillation system. The unit pays regular visits to the plant to perform the recycling operation and the recycled solvent is returned to the unit or storage, while arrangement is made to dispose of the still bottoms. SPaR charges a single fixed price for their service which depends on the type and quantity of the solvent to be processed. The charges include the cost of disposal, a payment for the contaminated solvent and the replacement of virgin solvent. The charges are for disposal of the still bottom at about $5.36 per gallon plus the cost of make-up solvent at $4.90 per gallon. For a typical 100 gal spent PERC which contains 40 percent oils, the net cost is about $299.80 or 3.00 per gallon.

Mobile on-site reclamation offers a number of benefits including no capital outlay for equipment, elimination of training and other labor costs associated with on-site distillation and elimination of the need for reformulation with dangerous stabilizers.

Aqueous extraction can be used to remove water soluble impurities. Pulsed extraction columns (reciprocating plate), countercurrent flow-packed flow-packed columns and simple agitated mixing vessels also allow good mixing and separation of water contaminated solvent. It should be noted that if the solvent contains any water soluble components such as methanol or ethanol, they would be removed in this process.

If the boiling point of the solvent is high (over 200°F) as with PERC, for example, the distillation can be done under a vacuum to minimize thermal decomposition of the solvent.

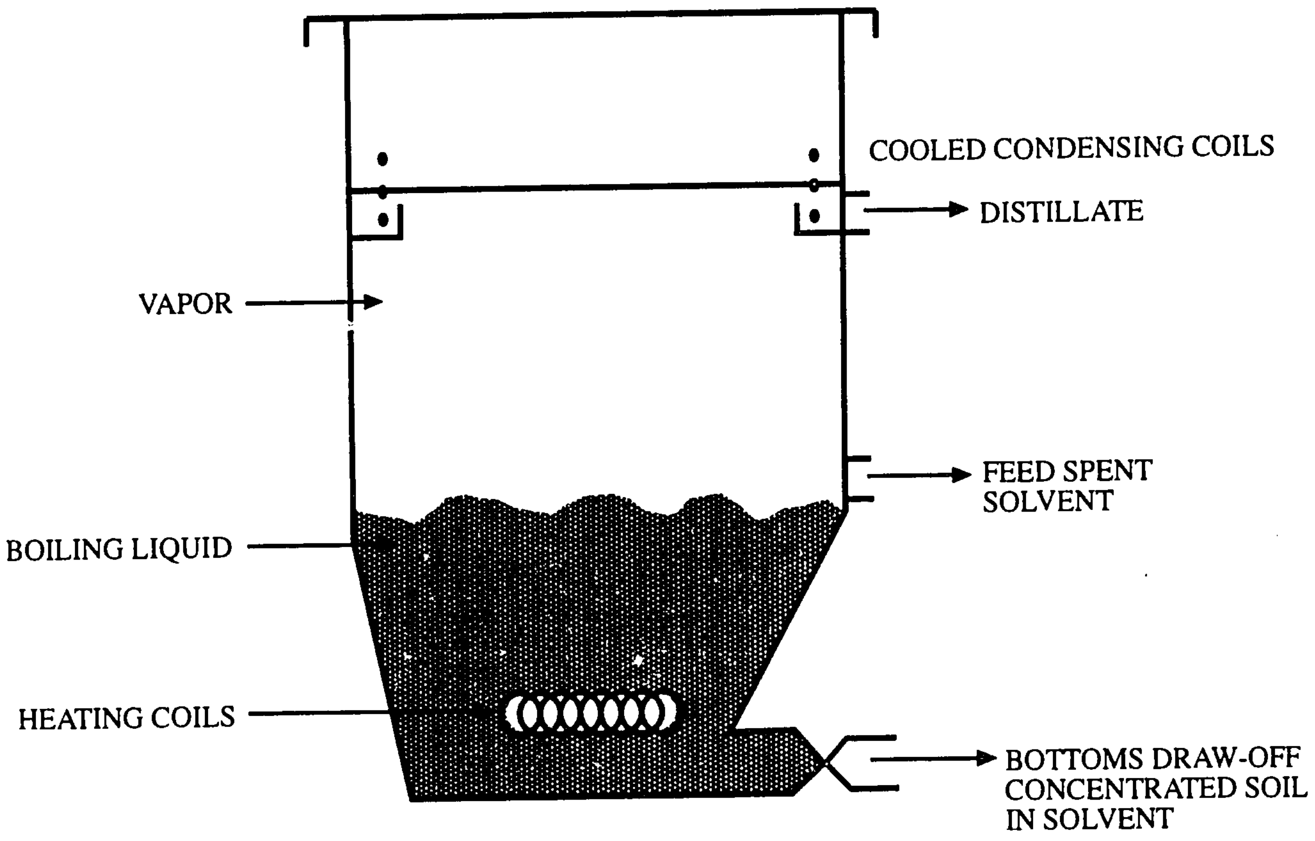
Another technique is to inject live steam into the solvent which forms an azeotropic mixture that boils at a lower temperature. The condensate of water and solvent is then separated by gravity.

There are many commercially available distillation systems ranging in capacity from 0.5 to 100 gal/hr with capital costs beginning at about $5,000 and operating costs of $1,000 per gallon per hour. The operating costs of the distillation apparatus includes labor, energy, cooling water, and maintenance. The largest component is labor. Of course, solvents have to be segregated in order for the distillation to be effective.

5.3.2 Off-Site Recycling

For generators who are not able either economically or technically to use in-house recovery techniques, off-site reclamation is an option. The recycler, under a contractual agreement, picks up the generator's contaminated solvent which can contain 50 to 90 percent by weight recoverable solvent, recycles it, and delivers purified solvent back to the generator or sells it

Exhibit 5-14
Single Plate, Batch or Continuous Still



back to other users. The sludges that result from the off-site reclamation contain small concentrations of solvents and are usually sent for destructive incineration.

In areas with large number of users, solvent reclamation is practiced profitably. In rural areas where large distances limit collection and transportation of the waste solvent, off-site recycling is less profitable.

Since the land disposal ban was implemented in the U.S., reclamation has gained widespread use because of high cost of other available options like incineration. However, many users question the quality of reclaimed solvent. The reluctance to use recycled solvents is justified to some extent since various kinds of contaminants may be found in some recycled material and no two reclamation firms follow the same quality control standards in recycling. Today, most reclaimers perform analysis and supply customers with fairly high purity solvent. The cost of recycled solvent varies depending on the situation, but ranges from 30 to 90 percent of the cost of virgin solvent.

A summary of recycling, reuse and recovery opportunities are provided in Exhibit 5-15.

Exhibit 5-15
Summary of Recycling, Reuse and Recovery Opportunities

Pollution Prevention Opportunity/Strategy	**Technique**
WASTE RECOVERY	
Heat Recovery	1) Employ the "Once-Through" approach which assumes that the fresh water flows matches those of the waste water - position pump suction properly
	2) Use the stratified sump type system in which the sump releases the hottest water available for BTU recovery and wastes the coolest water when excess is present
Size Recovery	1) Employ a size recovery scheme; the recovered size can be returned directly to the slashing operation make-up kettles
Caustic Recovery	1) Recover caustic baths from mercerizing operations; mercerization is always a continuous process, hence, these waste streams are fairly easily handled
Water Reuse	1) Use the same water in more than one process to reduce hydraulic loadings to treatment systems and reduce wastewater discharge
Dyebath Reuse	1) Recover and reuse the chemicals in the dyebath
	2) Move the dyebath back and forth between two or more machines
	3) Analyze or estimate the dye and chemical content of spent dye liquor
	4) Extract dye from the dyebath
	5) Reuse the bath for another dyeing
WASTE REUSE FROM OFF-SITE SOURCES	1) Find other uses for final wastes

Pollution Prevention Opportunity/Strategy	**Technique**
RECOVERY AND REUSE OF VAPORS	1) Channel solvent vapor and air stream to a carbon adsorption unit for recovery (Carbon Adsorption)
	2) Use fluidized bed technology in the adsorption of solvent on macroporous polymer particles (Polymeric Adsorption)
	3) Condense solvents to liquids using a reverse Brayton refrigeration cycle (Brayton Cycle Heat Pump)
	4) Use Membrane Separation Systems to separate and remove organic solvent from waste air streams
HOUSEKEEPING MEASURES	1) Employ proper procedures to start-up/shutdown the solvent scouring machine
	2) Perform solvent filling, scouring, draining, and transfer with enclosed piping systems
	3) Pump the solvent directly from the drum to the scouring machine
	4) Use leakproof couples to reduce transfer losses
	5) Monitor emissions
	6) Maintain proper planning and inventory control
	7) Repair visible leaks
	8) Conduct routine equipment inspections
RECYCLING OF WASTE SOLVENT	1) Perform on-site recycling by solvent reclamation, on-site distillation, single plate distillation, single stage distillation, and aqueous extraction
	2) Perform off-site recycling by off-site reclamation

CHAPTER 6

POLLUTION PREVENTION OPPORTUNITIES IN THE EGYPTIAN TEXTILE INDUSTRY

6.1 INTRODUCTION

The findings from three pollution prevention (P2) assessments conducted in the textile industry in Egypt are presented here. The assessments were conducted by the Environmental Pollution Prevention Project (EP3) component of the Energy Conservation and Environment Project (ECEP). The assessments demonstrate that significant pollution prevention opportunities exist in Egyptian textile facilities.

The P2 opportunities identified for the three facilities would result in a first-year net savings of LE 1,600,000. The one-time annual cost for implementing these measures would be LE 1,100,000. In addition to the economic benefit, implementing the identified measures at each of these facilities will help increase plant efficiency, product quality and worker productivity. It would also reduce worker exposure to toxic chemicals, reduce the quantity of wastes generated, and conserve water, energy and raw materials.

Assessments were performed at three facilities. To preserve the anonymity of the facilities, a two-letter facility identifier will be used throughout the remainder of this section. The facilities include: 1) a fabric production facility where garments made from wool, cotton, cotton polyester, wool/acrylic, and rayon are prepared, printed and dyed (Facility TB); 2) a sewing, dying, and finishing plant producing primarily T-shirts for export (Facility TC); 3) a silk and cotton weaving and finishing facility (Facility TA).

6.2 KEY POLLUTION PREVENTION EXAMPLES

The following examples highlight P2 opportunities that could be replicated at other Egyptian textile facilities. They illustrate the economic benefit and increased plant efficiency associated with pollution prevention.

6.2.1 Steam Heating

Steam is used as a heat source in several of the operations conducted by all three of the textile facilities examined in this section and can provide the facilities with a variety of opportunities for reducing production costs.

Three significant measures were identified for improving efficiency in plant TA. Heating at facility TA is achieved through a heat exchanger. This process is run by a stirring pump connected to a jet. The solution is withdrawn by the pump and injected into the nozzles of the jet. When the desired temperature is met on the upper end, the excess steam is not returned back to the boiler, but rather discharged to the treatment plant. Also, the process water inside the jet was cooled by passing softened water through the exchanger. The cooling water was also being discharged. The first measure pertains to the internal jet heat exchangers. Raw water is currently being used in the internal jet heat exchangers to cool the process water after which point it is discharged to the sewer. This water should be directed to a reservoir tank which will be utilized as the clean process feed water for process baths in both the winches and jets which require clean water. The cost of a new reservoir tank was estimated to be LE 5,000, and it would save the plant LE 10,000 annually. An opportunity was also identified to recover steam condensate. Steam condensate is not currently recovered because the condensate recycling pump failed too frequently to be repaired. Use of the proper pump would solve this problem. Savings would be LE 3,900 in saved water alone. The third opportunity identified involved improving the boiler efficiency by implementing a tune-up, preheating the #6 fuel to a temperature of 95-105 °C, replacing the eroded fuel nozzle, and decreasing the flue gas temperature. These measures would lead to a total annual savings of LE17,000 and would cost around LE 250 to implement. The combined annual savings of all of the measures related to steam heating at plant TA would be about LE 31,000.

At facility TB, steam is produced by an 8 ton per hour, fire tube boiler and a 4 ton per hour water tube marine boiler. Two additional boilers are used to heat the drying frames. Four measures to improve steam heating efficiency were identified for facility TB. Steam leaks were identified which allowed considerable volumes of steam to escape. It was calculated that repairing these leaks would save LE 12,000 worth of fuel used to heat the steam per year. The capital required to repair these leaks was minimal and this measure has already been implemented by regular maintenance staff at the facility. Second, in facility TB, an opportunity was found to harness waste heat (condensate) from the dye machines. The dye machines are equipped with a steam heated heat exchanger. It was found that the condensate was being lost as effluent. By capturing this condensate and pumping it to the boilers, efficiency could be improved in two ways. First, the lost heat could be saved; second, the need to treat that water could be eliminated, leading to a combined savings of LE 6,500 per year. Thirdly, insulation of the steam pipes in the boiler house and dye house would lead to annual savings of about LE 22,000 and would require a one-time cost of about LE 12,000. By far the measure with the greatest payback consists of installing a steamer after the pad on the preparation line. This steamer would allow cloth to be prepared in one run rather than two and would save on steam fuel, water, and labor. The combined savings of this measure equal LE 210,000 annually and are associated with a one-time cost of LE 200,000 to implement. Thus, the total annual savings achieved by implementing efficiency measures at facility TB, related only to steam heating, are equal to LE 250,000.

At plant TC, three measures were identified for improving efficiency related to steam heating. The first measure is the recovery of steam condensate. Steam is used as a heating medium by two types of heat exchangers. The first type is the open type while the second type is the closed heat exchanger. The condensate from the closed heat exchangers is dumped at the drain. This type of heat exchangers is used at the rotary printing machine, a curing machine, a stentor machine, two drying machines and two calendar machines. This steam condensate could be returned back to the boilers as feed water. Reusing the condensate steam reduces fuel consumption and demineralized water consumption. The total savings resulting from the implementation of this measure are estimated to be LE 80,000 with an initial investment of LE10,000. The second measure consists of tuning up the boilers. A portable, microprocessor-based, exhaust gas analyzer could be used. Currently the boilers have only a load control system that regulates the fuel system according to the steam pressure. Consequently, the amount of air that is supplied is based on present air/fuel ratio. There is no combustion control system to adjust the excess air according to variable combustion conditions. The proposed gas analyzer measures stack gas temperature, ambient temperature, oxygen, carbon monoxide, hydrocarbon emissions, and calculates the excess air factor and combustion efficiency. Facility TC estimates that it could save 5% of annual consumption, or LE 50,000, as a result of keeping the boiler properly tuned. And finally, it was estimated that simple insulation of the steam pipes would save an additional LE37,000 per year in fuel costs, with an initial capital cost of LE 30,000. Thus, total savings possible at facility TC from boiler operations alone would be LE 167,000 annually.

6.2.2 Washing, Treatment and Rinsing

A variety of opportunities for reducing production costs can be found in textile finishing facilities related to washing, treatment and rinsing of material and garments.

Facility TA found that it could save LE 100,000 annually by recycling its softener and its water. Currently, unused softener is discarded, wasting softener, water, and acetic acid. Recycling could be achieved by installing an external vessel to collect softener for use in the winches (the softener is not suited for use in the jets again). The one-time cost associated with this measure is estimated to be LE 35,000, corresponding to a 4 month payback period. The same facility also found that it could realize an annual savings of LE 35,000 by recycling its bleach rinse water. The second and third stages of winch bleaching consist of a hot rinse followed by a cold rinse. These rinses, it was determined, could be recycled back to the process to be used to make up the bleach bath and supply water for the hot rinse, a form of counterflow rinsing. The one time cost associated with this measure is LE 35,000, the equivalent of a one year payback period.

Facility TB found that it could save LE 29,000 annually just by utilizing the overflow from the pad on the rope washer range as fresh water for the washers, and by employing counter current flow on the rope washers. The total capital investment required in this case would be LE 2,500, requiring only a one month pay back period. Facility TB also found that it could save an additional LE 9,600 annually by using the overflow from the steam boxes in the merceration line as solution in the third caustic soda bath. The cost to implement this measure would be negligible. Thus, facility TB could save almost LE 40,000 annually by employing very basic measures related to treating and rinsing and would have only minimal costs.

At facility TC, it was found that recovering and reusing the dye liquor would lead to financial benefits of LE 195,000 annually, with an initial investment of LE 60,000. Dye bath reuse is an alternative to pretreatment systems for dye houses which discharge to public treatment systems. Dye bath reuse has been shown to reduce flow, BOD and COD loading up to 33%, and requires a smaller investment than a pretreatment system. A second measure, recovery of the bleaching liquor, would lead to equally impressive savings of LE 153,000 per year and would also require an initial investment of LE 60,000. It was determined that to collect the drain liquor of the bleaching process, a separate tank should be installed. By filtering the liquor and examining it, its suitability for reuse could be determined and it could be fed back. The payback period would be 4 months for the first measure and 5 months for the second measure.

6.2.3 Other High Return Opportunities

Other high return opportunities were identified at facility TC which include the installation of computers for color matching and a medley of minor measures which, cumulatively, also become significant. Using a color matching computer would be associated with an initial start-up cost of LE 240,000, and would lead to annual savings of LE 172,000 (a payback period of 17 months). The savings would be derived from a reduction in the consumption of colors, the number of defective fabrics, and the cost of wastewater treatment. The combination of general measures also identified, would lead to a total savings of LE 180,000 annually with an initial investment of LE 110,000, the equivalent of a 7 month payback period. These measures consist of improving the light intensity and ventilation system, cleaning looms in the weaving factory, fixing and reusing the dye machine covers, and cleaning the fabric handling and transportation equipment.

The key examples of P2 opportunities for the three textile facilities are summarized in Exhibit 6-1.

Exhibit 6-1
Summary of Pollution Prevention Opportunities at 3 Egyptian Plants

Name of Facility	Process	Pollution Prevention Option	Health and Environmental Benefits	Cost to Implement LE	Financial Benefits LE	Payback Period
TB	*Steam Heating* - preparation	Install a steamer after the pad on the preparation line	Allows cloth to be prepared in one run rather than two. Also saves steam, fuel, water and labor.	200,000.00	210,000	1 year
TB	*Steam Heating* - piping	Insulate steam pipes in the boiler house and dye house	Reduces fuel consumption by the boilers	12,000.00	22,000	7 months
TB	*Steam Heating* - piping	Repair steam leaks through the plant	Reduces steam losses and fuel consumption	0.00	12,000	immediate
TB	*Steam Heating* - condensate	Return condensate from jets to the boiler	Reduces fuel consumption in the boilers, saves water and chemicals used in the water treatment unit	1,800.00	6,500	3 months
TA	*Steam Heating* - jet cooling	Recycle jet cooling water	Reduced water use	5,000	10,000	6 months
TA	*Steam Heating* - condensate	Recover condensate	Reduces fuel consumption, saves water and chemicals used in treatment unit	NA	3,900	1 month
TA	*Steam Heating* - boiler	Tune boiler	Reduce fuel consumption	250	17,300	15 days
TC	*Steam heating* - condensate	Recover steam condensate	Reduces fuel consumption, reduces emission, reduces treated water consumption	10,000.00	80,000	6 weeks

Name of Facility	**Process**	**Pollution Prevention Option**	**Health and Environmental Benefits**	**Cost to Implement LE**	**Financial Benefits LE**	**Payback Period**
TC	*Steam Heating* - boilers	Tune-up boilers	reduces fuel consumption and emissions	0	50,000	immediate
TC	*Steam Heating* - piping	Insulate steam pipes	Reduces fuel consumption and emissions	30,000	37,000	16 months
TB	*Washing* -rope washer	Use the overflow from the pad on the rope washer range as fresh water for the washers. Establish counter current flow.	Reduce water consumption and treatment cost.	2,500	29,000	1 month
TB	*Mercerization*	Use the overflow from the steam boxes in the mercerization line to the third caustic soda bath.	Reduces water and NaOH consumption	100	9,600	4 days
TA	*Softening*	Recycle softener and water	Reduces softener discharges	35,000	100,000	4 months
TA	*Bleaching*	Recycle bleach rinse water	Reduces bleach rinse discharges	35,000	35,000	1 year
TC	*Dyeing*	Recover dye liquor	Reduces the dye stuff consumption and reduces wastewater treatment cost	60,000	195,000	4 months
TC	*Bleaching*	Recover bleaching liquor	Reduces bleach consumption and reduces wastewater treatment cost	60,000	153,000	5 months
TC	*Miscellaneous*	Improve light intensity Improve ventilation Clean looms and weaving factory Fix and reuse dye machine covers Clean the fabric handling and Transportation equipment	Reduces chemical, water and energy use	107,000	180,000	7 months

6.3 PLANT DESCRIPTIONS

Plant descriptions and brief process flow diagrams for each of the 3 plants assessed are provided in the following section. The section also includes a summary of the costs and savings associated with the P2 opportunities recommended for each plant.

6.3.1 Facility TA

Facility TA began operation in July 1993 with the commencement of sewing operations. The dye house began operations in April 1994 and had reached 50% of full capacity production by August 1994. The facility mainly produces T-shirts. Production grounds occupy about 7,000 square meters. A second story is attached to the office area. The plant employs about 750 people, 600 in sewing and material handling, 75 in dyeing and finishing, and 75 in administration. Energy supply consists of natural gas, electricity and steam from two boilers fueled with heavy fuel oil.

The production equipment consists of a small knitting line, a large number of sewing and cutting stations and a finishing department. The finishing department bleaches, washes, dyes, dries and presses cotton fabric. Dyeing is done in three open becks, called winches, and three pressurized jets. All water used in the finishing department is softened. The softener is regenerated after each 170 m^3 of throughput. All plant process waters pass through an industrial pre-treatment plant where solids are reduced by flocculation and the effluent is neutralized before discharge to the municipal sewer. Solids removed are either dried with a filter press and dumped onto the desert or dumped directly without dewatering.

The types of solid waste generated by the various operations include:

1. Remains of the cloth after sheering and sewing; they are mostly small pieces with different shapes, fabrics, and colors. Those materials are collected and, later sold.

2. Cartons:
Those are also collected and stored to be sold.

3. Metal vessels and canes are collected to be sold .

4. Plastic containers:
These are two categories, small and large size containers. Both are collected to be sold.

The steam generation plant is comprised of two fire tube boilers each of 4 t/h maximum capacity. The fuel used is #6 (bunker C) fuel. The boiler house itself contains two daily tanks, one for the light fuel (one ton capacity), used just for starting the burner; the second tank (3-ton capacity) is for the #6 fuel. The heavy fuel which is partially preheated is passed to the burner via a

136

secondary controllable steam heater for further preheating to the proper temperature. The feed water to the boiler is softened in a water treatment unit.

Steam is fed to the dye house through a 6-inch insulated pipe, which in turn, is connected to the jets and winches through a smaller size system of pipes. Water is heated up in the jets through the indirect heating by steam in a heat exchanger system.

A second main of steam, 4-inch in diameter comes from the boiler house to feed 2 calendars, a dryer, and a tumble dryer. The condensate from the different steam users is collected and returned back to the condensate tank in the boiler house through a 4-inch pipe. The same condensate tank is used for adding the make up water for the boilers. The tank is provided with an overflow mechanism which sometimes represents a kind of loss for the treated (softened) feed water.

6.3.2 Facility TB

Facility TB was founded in 1983 and began production in 1984. The facility occupies an area of 17,000 M^2. It employs 1,100 people and operates a single shift, while its dye house operates two shifts of 8 hours per day for 300 days per year. The major operations include greige weaving, dyeing and garment manufacturing.

The company produces garments for the men's and women's wear market. These garments are made from wool, cotton, cotton polyester, wool/acrylic, and rayon. Seventy five percent of the production is for the domestic market while approximately 25% is sold for export.

The main unit operations are:

- Fabric Preparation:
    - Plating
    - Bleaching
    - Mercerization
- Printing and Dyeing:
    - Printing
    - Jet Dyeing, Jigger Dyeing, and Pad-Batch Dyeing
- Treatment and Drying:
    - Drying
    - Singeing
    - Washing
    - Finishing
    - Sanforizing
    - Inspection

- Plant Services:
    - Steam Production
    - Water Treatment

6.3.3 Facility TC

The TC facility consists of 3 units. The first one is the weaving factory which produces about 6 million meters of fabric per year from about 3,000 tons of yarn. Most of the yarns used are cotton yarns, and some blend from cotton and polyester yarns. The second unit is the finishing and preparation factory which finishes the 6 million meters of fabrics produced per year by the weaving factory in addition to about 3 million meters of fabric per year for external customers.

The third unit is the utilities. Two Artesian wells are the only source of water in the plant. There is a water treatment plant which produces about 400 m^3/day of demineralized water for boilers use as well as about 1,000 m^3/day of soft water for the industrial purposes. Two water tube boilers generate about 20 tons of superheated steam per hour each. They consume about 6,000 ton of mazout (oil# 6) as a fuel in addition to about 600,000 liters of solar (oil# 2) consumed by an oil heater. Currently the waste water coming from all processes is collected together and drained to a channel.

The plant has about 2,000 workers and works for 3 shifts/day and 6 days/week, 300 days a year.

The current volume of production represents only 50% of the design capacity. This is due to the high competition in the local market..

The Weaving Factory: In the weaving operation, the length-wise yarns, which run from the back to the front of the loom, form the basic structure of the fabric and are called the warp. The crosswise yarns are the filling, and are called the weft. Yarns intended for the warp, pass through 3 operations to prepare them to withstand the strain of the weaving process.

The first one is the spooling, where the yarn is wound on spools or cones which are placed on a rack called a creal. In the second operation, the yarns, from this creal, are wound on a wrap beam. An interrupted length of hundreds of warp yarns results, all lying in parallel to one another. In the third operation, these yarns are unwound to be put through a sizing bath.

The sizing operation covers every yarn with a coating to prevent breaking or chafing during the weaving process. The plant uses a starch-based sizing process. The sized yarns are then wound onto a final warp beam to be ready for the looms. It has 712 looms of several types, where the yarns, which are winded in weft pipes, are interlaced into the warp yarns producing the woven fabric.

138

The Finishing and Preparation Factory: The raw fabrics contain warp sizing, oils, other additives, dirt and soil. They must be cleaned before they can be finished. Complete removal is necessary in order to finish, dye, and/or print fabrics effectively. If fabric is to be finished white, all natural color must be removed by bleaching. In this stage, the fabric is put through a desize steamer, washed, impregnated with a mild 3% solution of caustic soda, and pulled up into a large container that is equipped to maintain a temperature close to 100°C. After a certain period of time, the fabric is hauled out of the container and given a hot wash.

A small portion of the fabrics goes through the mercerization process when needed. Mercerizing increases the luster and strength of the fabric and increases its affinity for dyes. For mercerizing, the fabric passes through a cold, 16-32% solution of caustic soda. It is then stretched out on a tenter frame where hot-water sprays remove most of the caustic. A washer at the end of the tenter removes the balance of alkali.

The fabrics are dyed using several methods. The first one is the beck dyeing. Long lengths of fabric pass repeatedly, in tension-free rope form, through the dye bath until reaching the desired intensity of color. The second method is the jig dyeing. This is a procedure similar to beck dyeing, but with the fabric held at full width. The third method is the jet dyeing. Synthetic fibers are placed in a heated container and jets of dye solution are forced through it at high pressures. The plant washes fabric to be dyed twice in hot water before dyeing. After dyeing, they immerse the fabric into a hot saline solution as a fixative of the colors.

The facility uses the direct printing technique. The color is imprinted on the fabric in a paste form. Rotary screen printer is the method used where designs are printed on fabric by engraved rollers. The facility engraves the rollers in the plant. The number of rollers used depends upon the number of the colors in the design. After application, the ink is dried in two successive dryers.

Fabrics are moved to two tenter machines to dry then to the folding machines and finally to the inspection machines.

APPENDIX I
CASE STUDIES

EP3 CASE STUDIES

HBI-94-004-01, Pub. 10/31/94

Pollution Prevention Assessment for a Textile Dyeing Facility Serving Fabric Manufacturers

CASE STUDY

What is EP3?

The amount of pollutants and waste generated by industrial facilities has become an increasingly costly problem for manufacturers and a significant stress on the environment. Companies, therefore, are looking for ways to reduce pollution at the source as a way of avoiding costly treatment and reducing environmental liability and compliance costs.

The United States Agency for International Development (USAID) is sponsoring the Environmental Pollution Prevention Project (EP3) to establish sustainable programs in developing countries, transfer urban and industrial pollution prevention expertise and information, and support efforts to improve environmental quality. These objectives are achieved through technical assistance to industry and urban institutions, development and delivery of training and outreach programs, and operation of an information clearinghouse.

EP3's Assessment Process

EP3 pollution prevention diagnostic assessments consist of three phases: pre-assessment, assessment, and post-assessment. During pre-assessment, EP3 in-country representatives determine a facility's suitability for a pollution prevention assessment, sign memoranda of agreement with each facility selected, and collect preliminary data. During assessment, a team comprised of U.S. and in-country experts in both pollution prevention and the facility's industrial processes gathers more detailed information on the sources of pollution, and identifies and analyzes opportunities for reducing this pollution. Finally, the team prepares a report for the facility's management detailing its findings and recommendations (including cost savings, implementation costs, and payback times). During post-assessment, the EP3 in-country representative works with the facility to implement the actions recommended in the report.

Summary

This assessment evaluated a dye house serving a variety of fabric manufacturers. The objective of the assessment was to identify actions that would: (1) reduce the quantity of toxics, raw materials, and energy used in the dying process, thereby reducing pollution and worker exposure, (2) demonstrate the environmental and economic value of pollution prevention methods to the dyeing industry, and (3) improve operating efficiency and product quality.

The assessment was performed by an EP3 team comprised of an expert in textile dyeing and a pollution prevention specialist.

Overall, the assessment identified 37 pollution prevention opportunities -- classified as first, second, and third priority opportunities -- that could reduce energy use at this facility and avoid the release of over 14 metric tons of air emissions each year, in addition to unquantified reductions in the release of global warming gases and heavy metals. Water use could be reduced by 125,000 cubic meters per year, and chemical releases to surface waters could also be reduced. Finally, it may be possible to avoid the disposal of 330 cubic meters of solid waste per year.

Facility Background

This facility is a dye house serving fabric manufacturers. The facility operates two eight-hour shifts, six days per week, employing seventy shift workers and twenty technical and administrative employees. In 1992, the facility processed 350,000 kg of cotton and 360,000 kg of wool fabric.

Manufacturing Process

In general, cotton dyeing involves two procedures, desizing and bleaching, and dyeing. Each procedure involves a number of steps that must be carried out in proper sequence and under optimal conditions. For detailed depictions of these processes, see Figure 1. Wool dyeing also involves several procedures: (1) washing, (2) podding (heating thin wool fabrics in

EP3 is sponsored by the U.S. Agency for International Development.

lint washed off fabric, (4) leakage of detergent-laden water from the wool washing machines, (5) excessive pH of effluent from the decarbonizing acid bath, (6) excessively hot effluent, (7) excessive oil and grease and sulfate concentrations in effluent, (8) leakage from steam coils, (9) hydrogen sulfide generation at the wool laundry sump, (10) disposal of dry wool, cotton combings and shavings, and sodium sulfate bags (materials that could be recycled), (11) excessive air emissions of particulates, and (12) lint and sulfuric acid mist in the wool laundry room.

This facility uses about twice as much water as the average commission batch dyer its size; thus, many of the recommendations focus on reducing water consumption and the energy required to heat it for various dyeing processes.

Pollution Prevention Opportunities

The assessment identified almost 40 pollution prevention opportunities that could address the problems identified, with significant environmental and economic benefits to the facility. The assessment team prioritized these opportunities based on pollution prevented and implementation cost. Table 1 lists the high priority opportunities recommended for the facility and presents the environmental benefits, savings and implementation costs, and estimated payback period for each (a complete list of recommendations is available from the EP3 Clearinghouse). Many of the recommendations can be implemented with no capital investment. Further, many can be implemented almost immediately, and most are not dependent upon other projects for their initiation.

Of the 19 high priority opportunities recommended, the savings possible from implementing six have been quantified. These six recommendations will reduce operating costs by almost $106,000 per year for an initial investment of $1,900. The simple payback period for these changes is one week. Another $2,600 in investments is required to implement other changes whose savings potential cannot be quantified without further research.

Effect on the Environment

Implementation of the recommended actions will produce positive environmental impacts in three areas: reduced air emissions, lower water and chemical use, and reduced generation of solid waste.

Air Emissions. Many of the proposed changes will reduce steam consumption and lower fuel use, thereby reducing air emissions. Repairing all traps should reduce fuel consumption by 36 percent, or 454 metric tons of number 6 residual oil per year. The expected reductions in air emissions from this change total over 14 metric tons per year. In addition, this change will result in reduced carbon dioxide and heavy metal emissions.

Water and Chemical Use. When all rinsing changes have been implemented, the facility should consume half the water it currently does. The yearly reduction in water use will be about 125,000 cubic meters. Chemical use will decline due to a number of changes. Sulfate in the effluent will be reduced by more than 70,000 kg/year by changing to sodium chloride and filtering the decarbonizing acid bath.

Releases to the sewer of other chemicals such as dye, dye stabilizers, de-foamers, detergents, sodium hydrosulfite, bleach, optical brighteners, acetic acid, equalizers, and boiler treatment chemicals will be reduced as a result of the recommended changes. Among the changes that will affect chemical releases are: (1) better process controls, (2) screening drains and cleaning sumps regularly to prevent sulfide generation, (3) preventing beck boil-over, (4) repairing coil steam leaks that contaminate boiler feed water and process baths, (5) using a lower-foaming jet-dye detergent, (6) calibrating and shimming becks, (7) repairing and modifying becks and wool laundries, and (8) determining sizing formulae. Until these changes are made, it is not possible to calculate the degree to which releases will be reduced.

Solid Waste. Solid waste discarded by the facility consists mainly of sulfate chemical bags and shavings and combings from fabric finishing. Assuming that the eight sulfate bags generated per day fill one large (0.1 cubic meter) garbage bag and that the combings fill ten bags per day, the yearly un-compressed volume of these solid wastes is 330 cubic meters. If both wastes are recycled, this volume of waste can be reused at least once before being discarded.

For Further Information

For further information on this assessment or other activities sponsored by EP3, call the EP3 Clearinghouse at (703) 351-4004, send a fax to (703) 351-6166, or on Internet apenderg@habaco.com.

Pollution Prevention Assessment for a Textile Dyeing Facility Serving Fabric Manufacturers

CASE STUDY

What is EP3?

The amount of pollutants and waste generated by industrial facilities has become an increasingly costly problem for manufacturers and a significant stress on the environment. Companies, therefore, are looking for ways to reduce pollution at the source as a way of avoiding costly treatment and reducing environmental liability and compliance costs.

The United States Agency for International Development (USAID) is sponsoring the Environmental Pollution Prevention Project (EP3) to establish sustainable programs in developing countries, transfer urban and industrial pollution prevention expertise and information, and support efforts to improve environmental quality. These objectives are achieved through technical assistance to industry and urban institutions, development and delivery of training and outreach programs, and operation of an information clearinghouse.

EP3's Assessment Process

EP3 pollution prevention diagnostic assessments consist of three phases: *pre-assessment*, *assessment*, and *post-assessment*. During *pre-assessment*, EP3 in-country representatives determine a facility's suitability for a pollution prevention assessment, sign memoranda of agreement with each facility selected, and collect preliminary data. During *assessment*, a team comprised of U.S. and in-country experts in both pollution prevention and the facility's industrial processes gathers more detailed information on the sources of pollution, and identifies and analyzes opportunities for reducing this pollution. Finally, the team prepares a report for the facility's management detailing its findings and recommendations (including cost savings, implementation costs, and payback times). During *post-assessment*, the EP3 in-country representative works with the facility to implement the actions recommended in the report.

Summary

This assessment evaluated a dye house serving a variety of fabric manufacturers. The objective of the assessment was to identify actions that would: (1) reduce the quantity of toxics, water, and energy used in the dyeing process, thereby reducing pollution and worker exposure, (2) demonstrate the environmental and economic value of pollution prevention methods to the dyeing industry, and (3) improve operating efficiency and product quality.

The assessment was performed by an EP3 team comprised of an expert in textile dyeing and a pollution prevention specialist.

Overall, the assessment identified eleven pollution prevention opportunities that could reduce energy use at this facility and avoid the release of 0.5 metric tons of air emissions each year. Water use could be reduced by nearly 70,000 cubic meters per year, and chemical releases to surface waters could also be reduced. Two ofthe opportunities - recycling bleach rinse water and capturing the heat in boiler blowdown water - reduced annual operating costs by about $9,000 for an initial investment of $1,700.

Facility Background

This facility is a dye house serving fabric manufacturers. The facility operates two twelve-hour shifts, six days per week. In 1992, the facility wet-processed about 960,000 kg of fabric, consisting primarily of cotton-synthetic blends.

Manufacturing Process

Fabric dyeing at this facility involves a number of steps that must be carried out in proper sequence and under optimal conditions. The process consists of filling tanks containing fabrics with water, and sequentially (1) heating, (2) rinsing, (3) adding dyes, bleaches, and other chemicals, (4) cooling, and (5) combing or ironing the fabric as shown in Figure 1 (a more detailed process flow is available from the EP3 Clearinghouse). This process involves at least eight complete

Figure 1: Overview of Facility's Textile Dye Process

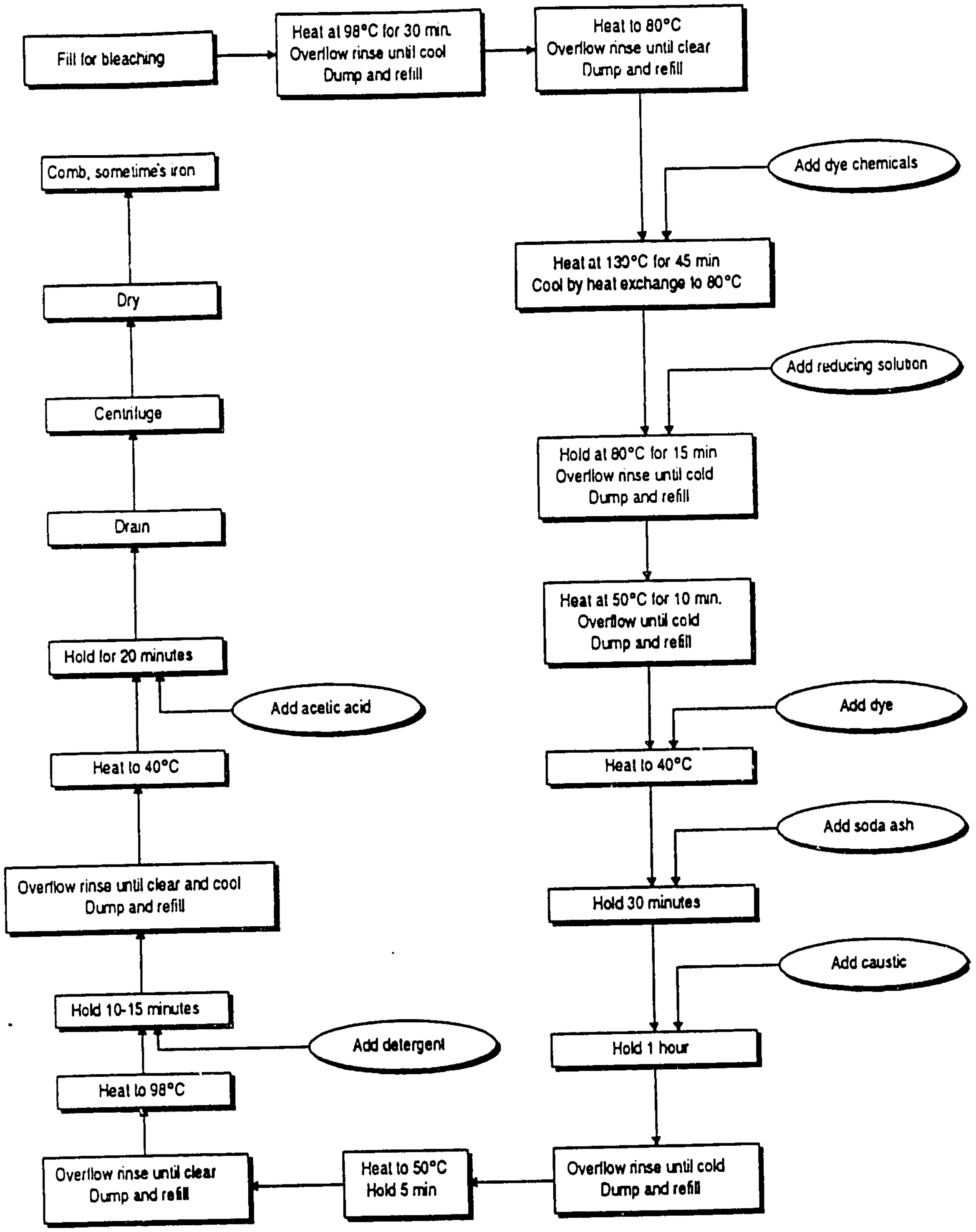


Table 1: Summary of Recommended Pollution Prevention Opportunities

Unit Operation	Pollution Prevention Opportunity	Environmental Benefit and Cost Savings	Capital Cost to Implement
Bleach Rinsing	Reduce water use, recover process chemicals and heat by recycling bleach rinse water.	Reduce water use by 23,000 cubic meters per year. Reduce water costs by $6,300 per year.	$1,200 to replumb tanks
Dye Rinsing	Reduce water use by recycling second dye rinse.	Reduce water use by 43,000 cubic meters per year. Reduce water costs by $12,800 per year.	$2,400 for two tanks and plumbing.
Boiler	Recover heat from boiler blowdown.	Reduce fuel used by $2,700 per year, reduce temperature of effluent.	500
Dye Process	Reduce liquor ratio in jet dyeing.	Reduce water use by up to 4,800 cubic meters per year. Reduce water costs by $1,300 per year.	None
Chinese Reactive Dyes	Control dye process using Fong equipment.	Reduce redye and chemical costs (unquantified).	None
Dye Process	Use Fong equipment to determine acetic and formic acid concentrations for specific dyes.	Reduce use of chemicals, reduce BOD 5 of effluent (unquantified).	None
Reactive Dyes	Determine actual price break point for one and two-step dyeing.	Reduce dye use, decrease cost of dyeing (unquantified).	None
Dispersed Red 60 Dye	Change dyes to improve heat fastness.	Reduce dye in effluent, reduce dye costs (unquantified).	None
Effluent	Reduce suspended solids in effluent by installing screens	Keep effluent in compliance.	120
	Reduce sulfide in effluent by aeration and exposure to light.	Reduce sulfide in effluent, prevent sewer deterioration.	120
	Determine effluent concentrations for controlled parameters, determine reduction priorities.	Keep effluent in compliance, identify priority pollutants for reduction.	$600 for testing
TOTALS		$9,000 to $23,000 annually, plus unquantified opportunities.	$2,500 to $5,000

changes of water, and at least six additions of dyes, bleaches, and other chemicals.

Existing Pollution Problems

At the time of the assessment, there were a number of pollution problems at the facility, including (1) excessive water use in the rinsing, dyeing, and bleaching processes, (2) excessively hot effluent, (3) unnecessary energy use due to ineffective heat recovery, (4) excessive BOD of effluent, and (5) overuse of dyes and other chemicals.

Pollution Prevention Opportunities

The assessment identified eleven pollution prevention opportunities that could address the problems identified, with significant environmental and economic benefits to the facility. Table 1 lists the opportunities recommended for the facility, and presents the environmental benefits, savings and implementation costs for each. Many of the recommendations can be implemented with no capital investment. Further, many can be implemented immediately, and most are not dependent upon other projects for their initiation. The recommendations can be grouped into four general categories: (1) reductions in water use, (2) modifications to recover waste heat, (3) process control modifications, and (4) reductions in effluent contaminant concentrations.

Reductions in Water Use. Water use at the facility is now near the limits of system capacity. The resulting low water pressure increases the cycle time for fabric processing by extending the time needed to fill jets with water. Any reduction in water use would therefore increase productivity as well as reduce water purchase costs. If large quantities of the same colored fabric are dyed in succession, countercurrent rinsing can be built into the structure of jet dyeing equipment. This would reduce water use, while maintaining the same quality of final product.

Bleach rinsing involves two successive overflowing rinses. Recycling the second bleach rinse back into the process for use in the first rinse could begin immediately to reduce water use; water reuse is standard practice on large through-put machinery. Assuming that half of the 8,200 liters used for the two bleach rinses is reused and that 5,680 loads per year are processed, the quantity of water that could be saved is 23,300 cubic meters per year, saving over $6,400. If rinse processes are modified to use recycled second rinse water, the additional savings would be 43,300 cubic meters per year worth $12,800, for a total savings of nearly 70,000 cubic meters per year worth almost $20,000. If water from both rinses is recycled, total water use could be reduced by about 25 percent.

Modifications to Recover Waste Heat. Currently, after polyester dyeing, the solution in the jet is cooled with a heat exchanger from 130°C to 80°C. By retrofitting the boilers with a continuous blowdown system, and routing the water from that system through the heat exchange coils in the two steel tanks, heat could be recovered into the used jet cooling water. Water for both fabric processing and boiler feed could be drawn from this tank, which would make maximum use of the heat from both jet cooling and boiler blowdown water. The savings would be about $2,700, assuming a 50 percent efficient heat transfer mechanism. Reusing rinse waters and capturing heat from the boiler blowdown also reduces the temperature of effluent. This is significant because effluent has sometimes exceeded 75°C, when the standard is 35°C.

Process Control Modifications. Jet dyeing equipment of the type used at the facility could be run at lower liquor ratios than the current 10:1, perhaps as low as 5:1. Reducing the liquor ratio to 5:1 would save 4,800 cubic meters of water per year, worth over $1,300. Additional unquantified savings might be gained through better dye utilization. In addition, the facility could use a dye process simulator to realize significant savings by individualizing dye process formulae to the facility's unique needs. The facility could also use this equipment to help optimize the use of chemicals such as acetic and formic acids, which are the two largest contributors to biological oxygen demand in the effluent.

Use of less expensive Chinese reactive dyes requires a two-step process that consumes more time, water, and energy than the one-step process that can be used with more expensive European dyes. The facility can conduct a detailed study of these two methods, comparing the cost of all inputs, not just the purchase price of the dye to determine which dye type best meets the facility's overall manufacturing goals.

Reductions in Effluent Contaminant Concentrations. The facility could install parallel bar screens in the jet room where drains meet and at the entrance to the main sewer sump to reduce the amount of total suspended solids and sedimentable solids from fabric lint in the facility's effluent. More efficient removal of lint would reduce the amount of organic material in the sump, thereby depriving bacteria of food. Sulfide and heat in the effluent also may be reduced by replacing the cover on the sump with a grate that allows light and air to enter. This would promote oxygenation, allow hydrogen sulfide to dissipate, and increase heat exchange, thereby cooling the effluent.

Effect on the Environment

Three of the proposed changes could reduce steam consumption and lower fuel use, thereby reducing air emissions. Recapturing the heat from blowdown water is estimated to reduce fuel consumption by 2.4 percent or 19 metric tons of residual Number 5 oil per year.

Other proposed changes include recovering the heat in recycled bleach water and recovering the heat in recycled dye rinse waters, which could result in addition energy savings. Additionally, these changes will reduce emissions of carbon dioxide and heavy metals.

By undertaking both bleach and dye rinse recycling projects, the facility could reduce water consumption by up to 70,000 cubic meters per year. This also will reduce chemical use because bleach chemicals will be recovered for reuse. By using a dye process simulator, the facility could reduce the use and release of acetic acid, formic acid, and dyestuffs, major contributors to BOD levels in the facility's effluent.

For Further Information

For further information on this assessment or other activities sponsored by EP3, call the EP3 Clearinghouse at (703) 351-4004, send a fax to (703) 351-6166, or on Internet apenderg@habaco.com.

HBI-94-011-01, Pub. 10/31/94

Pollution Prevention Assessment for a Textile Dyeing Facility

CASE STUDY

What is EP3?

The amount of pollutants and waste generated by industrial facilities has become an increasingly costly problem for manufacturers and a significant stress on the environment. Companies, therefore, are looking for ways to reduce pollution at the source as a way of avoiding costly treatment and reducing environmental liability and compliance costs.

The United States Agency for International Development (USAID) is sponsoring the Environmental Pollution Prevention Project (EP3) to establish sustainable programs in developing countries, transfer urban and industrial pollution prevention expertise and information, and support efforts to improve environmental quality. These objectives are achieved through technical assistance to industry and urban institutions, development and delivery of training and outreach programs, and operation of an information clearinghouse.

EP3's Assessment Process

EP3 pollution prevention diagnostic assessments consist of three phases: *pre-assessment*, *assessment*, and *post-assessment*. During *pre-assessment*, EP3 in-country representatives determine a facility's suitability for a pollution prevention assessment, sign memoranda of agreement with each facility selected, and collect preliminary data. During *assessment*, a team comprised of U.S. and in-country experts in both pollution prevention and the facility's industrial processes gathers more detailed information on the sources of pollution, and identifies and analyzes opportunities for reducing this pollution. Finally, the team prepares a report for the facility's management detailing its findings and recommendations (including cost savings, implementation costs, and payback times). During *post-assessment*, the EP3 in-country representative works with the facility to implement the actions recommended in the report.

Summary

This assessment evaluated a textile dyeing facility. The objective of the assessment was to propose a program of pollution prevention that would: (1) reduce the quantity of toxics, raw materials, and energy used in the manufacturing process, thereby reducing pollution and worker exposure, (2) demonstrate the environmental and economic value of pollution prevention methods to the dyeing industry, and (3) improve operating efficiency and product quality.

The assessment was performed by an EP3 team comprised of an expert in textile dyeing and a pollution prevention specialist.

Facility Background

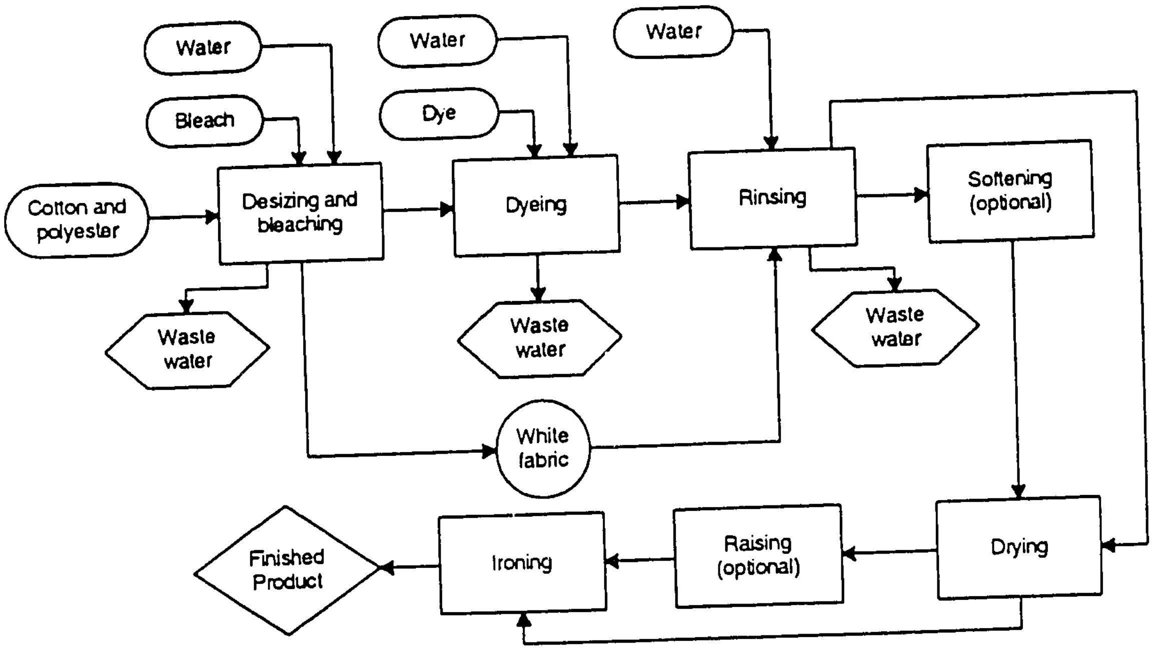
This facility is an integrated textile mill. Starting with polyester and rayon viscose fibers, the facility produces dyed yarn and fabric with an average content of 65 percent polyester and 35 percent rayon. The facility employs 270 workers who work 296 days per year. In 1993, production volume was 1,134,059 kg of material dyed, with an additional 1,227,974 kg of fabric finished but not dyed.

Manufacturing Process

Textile dyeing at this facility involves a number of steps that must be carried out in proper sequence and under optimal conditions. In general, the process involves filling tanks containing fabrics with water, and sequentially (1) heating, (2) rinsing, (3) adding dyes, bleaches, and other chemicals, (4) cooling, and (5) combing or ironing the fabric. This process involves numerous changes of water, and several additions of dyes, bleaches, and other chemicals. All fabric is dyed in jets with nominal capacities of 50 kg, 150 kg, 350 kg, and 750 kg of fabric. Yarn is dyed in a 200 kg cone-dryer.

EP3 is sponsored by the U.S. Agency for International Development.

Figure 1: Overview of Textile Processing



Existing Pollution Problems

At the time of the assessment, there were a number of pollution problems at the facility, including excessive: (1) use of water, (2) use of chemicals, (3) suspended solids concentrations in wastewater, (4) energy use due to lack of process standardization, leaking steam traps, and lack of a peaking generator, and (5) emissions from the oil-fired boiler.

Pollution Prevention Opportunities

The assessment identified eight pollution prevention opportunities that could address the problems identified above, with significant environmental and economic benefits to the facility. **Table 1** lists the opportunities for pollution prevention recommended for the facility, and presents the environmental benefits, savings and implementation costs for each.

Of the opportunities identified, three were studied in enough detail to quantify potential savings. For an investment of just under $11,000, the facility can reduce its water and salt consumption and save about $7,000 per year. The average payback period for these actions is approximately 20 months. Additional savings from bleach rinse recycling, steam trap repair, and boiler combustion efficiency changes were not quantified.

Recycling of Cone-dye Cooling Water. Well water with a hardness of approximately 600 ppm is pumped to a tank with a capacity of 60 cubic meters. From there, it is sent through a softener that reduces hardness to 3-5 ppm. This softened water is used for most factory processes. The cone-dyeing operation uses soft water for non-contact cooling in two places. The dye bath is cooled by passing soft water through the jacket of the dye tank. Non-contact cooling water is also used to cool the dye bath recirculating pump packing gland. Recycling these two streams is an opportunity and could be accomplished by sending the water back to the soft water pool that at the present time receives the cooling water from the jet dryers.

Table 1: Summary of Recommended Pollution Prevention Opportunities

Unit Operation	Pollution Prevention Action and Environmental/ Product Quality Benefit	Cost	Financial Benefit	Payback Period
Recycling of dye cooling water	Install piping and valves - conserves water.	$750	$400 per year	20 months
Recycling of air conditioning system water	Install piping and a tank - conserves water and chemicals.	$6,700	$4,900 per year	14 months
Softener system	Install a digital hardness monitor - conserves water and chemicals.	$3,500	$1,700 per year	24 months
Solids in effluent	Install screens in drain lines - reduces pollutant level in wastewater.	$600	To be determined	To be determined
Operator work system	Deliver training - reduces power and water consumption.	To be determined	To be determined	To be determined
Steam traps	Implement maintenance plan - reduces VOCs.	To be determined	To be determined	To be determined
Bleaching	Recycle rinse water - reduces use of water and chemicals.	$2,200	To be determined	To be determined
Boilers	Install a digital monitoring system - reduces emissions.	$1,000	To be determined	To be determined
Power Consumption	Install a peak load generator.	To be determined	To be determined	To be determined
TOTALS		$14,750	$7,000	

Recycling of Air Conditioner System Water. The air conditioner systems for the spinning and weaving rooms use soft water evaporation for cooling. The water currently used is taken from the softeners that serve the dye room. Fifty percent of this water is lost to evaporation, while the rest is dumped into the sewer system. This water use has caused problems in the dye room by causing shortages of soft water. The plant has purchased, but not installed, new softeners solely to produce water for the air conditioner system. When the new softeners are installed, the non-evaporated air conditioning system water should be recycled back to the new softener system.

Improving Softener Regeneration and Service. The current dye room softener system has three softeners, each of which treat well water. In the wash, regeneration, and rinse steps, the operators calculate the water hardness using a colorimetric method. The wash time is excessive and the point at which the softeners are regenerated is chosen solely on the basis of time since the last regeneration, resulting in the loss of soft water. A digital system should be installed to determine the rinsing and service hardness end points, allowing operators to determine the exact end point for the wash period and the maximal supply capacity of each softener.

Reduce Suspended Solids In Effluent. Five screens should be installed in dye room drains with the objective of reducing suspended solids in the effluent. The screens should be designed and installed to allow easy periodic cleaning. It is possible that in the near future the plant will need to install an industrial waste water treatment system; any decrease in loading now will allow a reduction in waste water treatment plant initial investment and running cost.

Improve Worker Training. Operators of the dye machines have different methods for operating each machine, even though a procedure sheet is supposedly followed. At each shift change, the new operator switched to a different method, e.g., increasing the number of rinsing steps or changing the timing for the different processes. Because of this lack of process standardization, there are energy, water, and chemical losses. Training courses in standard operating procedures should be conducted.

Develop a Maintenance Plan for Steam Traps. Heat transfer losses caused by leaking steam traps amounts to about 10-15 percent of energy costs. Using leaking steam traps not only wastes energy, but also results in inefficient dye bath heating and the cost of damage to steam lines, valves, fittings, and other equipment. A training course for workers in the operation of ultrasonic equipment should be established and a preventive plan for maintenance of steam traps should be developed.

Recycling Bleaching Process Rinse Water. There is an opportunity to recycle rinse waters from the bleaching process by installing a 25 cubic meter tank to store the rinse water of one batch and use it for the one that follows. Thirty-six tons of product would need to be bleached to recover the initial $2,200 investment.

Improve Boiler Combustion Efficiency Monitoring. The combustion efficiency of the oil-fired boiler is not monitored continuously, but measured by an outside contractor four timer a year. Installation of a digital monitoring system will allow the efficiency of the combustion to be determined whenever parameters change, such as when a new lot of oil is received. This change will result in reductions in fuel use and particulate matter emissions. Payback time will depend on the amount of combustible efficiency improvement.

Utilization of a Peaking Generator. During 1993, the factory paid a total of $105,600 in maximum and peak demand power charges. Installation of a peaking generator could yield substantial reductions in net power costs, although net emissions effects will be negligible. If a natural gas generator is chosen and bio-gas from the local landfill is used, there may be a small net positive effect on emissions. While the size, and therefore cost, of the needed generator cannot be calculated, other textile plants have indicated a payback time of approximately 11 months.

For Further Information

For further information on this assessment or other activities sponsored by EP3, call the EP3 Clearinghouse at (703) 351-4004, send a fax to (703) 351-6166, or on Internet at apenderg@habac.com.

Pollution Prevention Assessment for a Textile Dyeing Facility

CASE STUDY

What is EP3?

The amount of pollutants and waste generated by industrial facilities has become an increasingly costly problem for manufacturers and a significant stress on the environment. Companies, therefore, are looking for ways to reduce pollution at the source as a way of avoiding costly treatment and reducing environmental liability and compliance costs.

The United States Agency for International Development (USAID) is sponsoring the Environmental Pollution Prevention Project (EP3) to establish sustainable programs in developing countries, transfer urban and industrial pollution prevention expertise and information, and support efforts to improve environmental quality. These objectives are achieved through technical assistance to industry and urban institutions, development and delivery of training and outreach programs, and operation of an information clearinghouse.

EP3's Assessment Process

EP3 pollution prevention diagnostic assessments consist of three phases: *pre-assessment*, *assessment*, and *post-assessment*. During pre-assessment, EP3 in-country representatives determine a facility's suitability for a pollution prevention assessment, sign memoranda of agreement with each facility selected, and collect preliminary data. During *assessment*, a team comprised of U.S. and in-country experts in both pollution prevention and the facility's industrial processes gathers more detailed information on the sources of pollution, and identifies and analyzes opportunities for reducing this pollution. Finally, the team prepares a report for the facility's management detailing its findings and recommendations (including cost savings, implementation costs, and payback times). During *post-assessment*, the EP3 in-country representative works with the facility to implement the actions recommended in the report.

Summary

This assessment evaluated a textile dyeing facility. The objective of the assessment was to propose a program of pollution prevention that would: (1) reduce the quantity of toxics, water, and energy used in the manufacturing process, thereby reducing pollution and worker exposure, (2) demonstrate the environmental and economic value of pollution prevention methods to the dyeing industry, and (3) improve operating efficiency and product quality.

The assessment was performed by an EP3 team comprised of a US expert in textile dyeing, a US pollution prevention specialist, in-country EP3 staff, and local consultants.

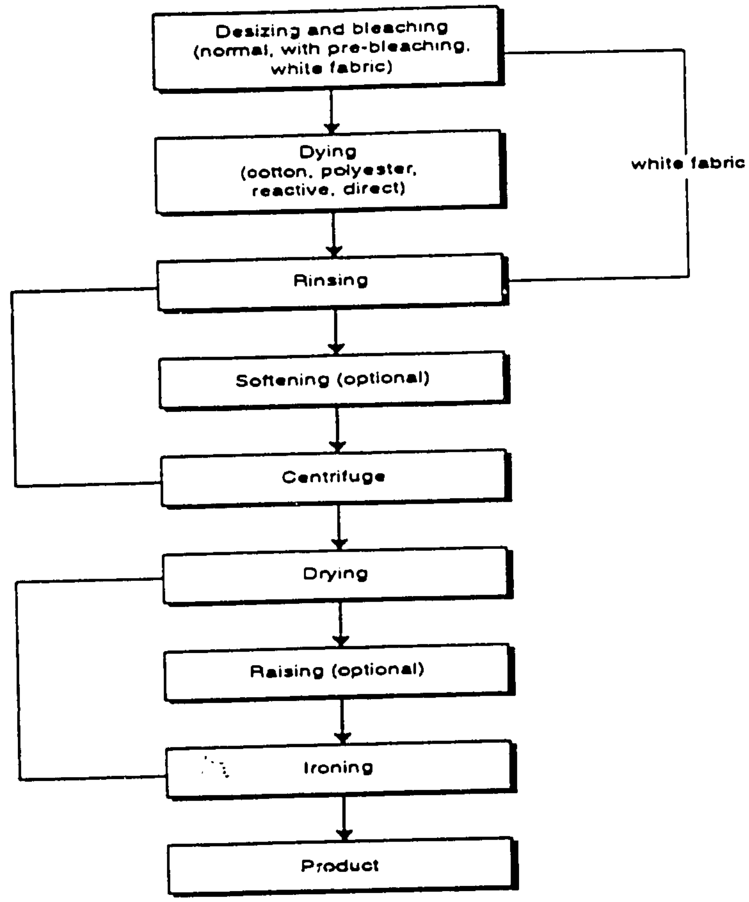
Overall, the assessment identified five pollution prevention opportunities that could reduce energy use at this facility and avoid the release of over 5.8 metric tons of air emissions each year, in addition to unquantified reductions in the release of global warming gases and heavy metals. Water use could be reduced by 46,700 cubic meters per year, and chemical releases to surface waters could also be reduced. The reductions in chemical releases require more research and development before they can be quantified.

Facility Background

This facility is a dye house that produces mostly acrylic yarn and fabrics. The facility operates three eight-hour shifts, six days per week. The facility typically wet-processes about 1,600 tons of yarn or fabric per year.

EP3 is sponsored by the U.S. Agency for International Development.

Figure 1: Overview of Facility's Textile Processing



Manufacturing Process

Textile dyeing involves a number of steps that must be carried out in proper sequence and under optimal conditions. In general, the process involves filling tanks containing fabrics with water, and sequentially (1) heating, (2) rinsing, (3) adding dyes, bleaches, and other chemicals, (4) cooling, and (5) combing or ironing the fabric as shown in **Figure 1** (a more detailed process flow is available from the EP3 Clearinghouse). This process involves numerous changes of water, and several additions of dyes, bleaches, and other chemicals.

Existing Pollution Problems

At the time of the assessment, there were a number of pollution problems at the facility, including excessive (1) hot effluent, (2) water use in overflow rinse process, (3) discharge of lint and other solids from wet process machines, (4) salt consumption in the water softening process, and (5) discharge of water and reactants from first rinse bleach solutions.

Pollution Prevention Opportunities

The assessment identified five pollution prevention opportunities that could address the problems identified, with significant environmental and economic benefits to the facility. **Table 1** lists the opportunities recommended for the facility, and presents the environmental benefits, savings and implementation costs for each. One of the recommendations can be implemented with no capital investment. Further, many can be implemented in less than six months, and are not dependent upon other projects for their initiation.

Table 1: Summary of Recommended Pollution Prevention Opportunities

Unit Operation	Pollution Prevention Action and Environmental/ Product Quality Benefit	Cost	Financial Benefit	Payback Period
Hot water discharges	Recover heat from effluent - reduces air emissions and wastewater temperature.	$3,000	$23,000 per year	1.5 months
Rinsing	Replace overflow rinsing with fill and dump rinsing and reduce fill volume - reduces liquid wastes.	None.	$8,900 per year	Immediate
Waste water discharges	Use lint traps in effluent to reduce suspended solids and other contaminants - reduces waste water solids, sulfur and other pollutants.	$100	To be determined	To be determined
Softening	Reduce salt use by reuse of wash water - reduces chlorides content in waste water	$700	$2,300 per year minimum	3.5 months
Bleaching	Reuse first bleach rinse water - reduces waste water volume.	$9,000	$1,600 per year	5.6 years
TOTALS		$12,800	$35,800 per year	

Of the five opportunities recommended, the savings possible from implementing four have been quantified. These four recommendations, which include capturing the heat in waste water, improving rinsing operation, reducing salt consumption, and recycling bleach rinse water, will reduce operating costs by about $36,000 per year for an initial investment of $13,000. The simple payback period for heat recovery is 1.5 months. For salt use reduction, it is 3.5 months. An investment of $9,000 is required to implement first rinse bleach water reuse, with a payback period of 5.6 years.

Recovery of Heat from Effluent. Substantial amounts of money are expended to generate the heat required for most of the wet processes. Heated water or cooling water with an increased temperature is discharged to the sewer system, containing about one third of the total heat that is generated by the boilers. Heat can be transferred to cold soft water through a pipe coil exchanger submerged in a waste water retention tank. Recovered heat should go to a warm water storage tank to feed the water that will be subsequently steam heated. Heat exchange will not only reduce effluent temperature, but will also regulate waste water flow, pollutant content, and pH, thus reducing peak values and making compliance with effluent standards easier. To avoid or reduce the undesirable settling of lint or other materials in the heat exchange tank, it is advisable that heat recovery be implemented after lint traps are installed.

Modify Rinsing Processes. Continuous overflow rinsing is very inefficient in terms of water use and can always be replaced by a number of batch rinsing processes where tanks are filled and then dumped completely before refilling. Specifically, overflow rinsing should be changed to fill and dump rinsing for rayon-linen fabric, acrylic yarn, and wool yarn dyeing, and full tank fill and dump rinsing should be changed to partial tank fill and dump rinsing for wool and acrylic fabrics.

Use of Lint Traps. Presently, all lint produced by the wet process machines goes to the sewer. Lint removal can be accomplished very easily at the generation points by using grids or parallel bar screens. Lint removal will reduce the solids content of effluent, reduce sulfur and other contaminants that result from decomposition of natural fibers, reduce the frequency of sewer obstructions, recover fiber that can be sold, and will make it possible to detect abnormal fiber losses. Lint removal requires regular and frequent inspection and cleaning of the lint traps.

Reduction of Salt Consumption. Regeneration of each softener takes an average of 2.5 cubic meters of saturated solution of sodium chloride plus 8 to 10 cubic meters of hard water, used for backwashing the resin and rinsing the removed hardness and brine solution. Rinsing is considered complete when hardness is as low as 2 mg/l. In the period when rinse water hardness is between that of untreated water from wells (about 500 mg/l) and 2 mg/l, it still contains some of the salt excess that is being removed. If this water, which is low in hardness and high in salt concentration, were used to prepare brine for the next regeneration, the regeneration process would be improved and the use of salt and water would be reduced.

Reuse of Bleaching First Rinse Water. Bleach solutions can be reused in the same process, saving water and reactants. Experiments should be run before final implementation to ensure that recycling is feasible and product quality is not impaired. If it is feasible, tanks, pumps, and all necessary piping and valves should be installed, and operators should receive the necessary training.

Effect on the Environment

Air Emissions. One of the proposed changes will reduce steam consumption and lower fuel use, thereby reducing air emissions. Only the savings that can be gained through recovering the heat from effluent have been quantified. Recapturing the heat from effluent should reduce fuel consumption by 7.5 percent of 189 metric tons of Number 180 oil per year. The expected reductions in air emissions from this change total about 5.8 metric tons per year. In addition, this change will result in reduced carbon dioxide and heavy metal emissions.

Liquid Wastes. Heat recovery from effluent would reduce the average effluent temperature from 36°Celsius to 32°or less, depending on the amount recovered, and will also distribute it more evenly in time. Even though the facility's effluent temperature is not a problem on average, the heat recovery system will be more effective in reducing the temperature precisely when it is at the higher levels.

If rinse water reduction, reuse of resin regeneration wash water, and reuse of bleach rinse water projects are implemented, the facility could consume 46,700 cubic meters (6 percent) less water than it now does. Reuse of regeneration wash water also will reduce the chloride content in water.

Removal of lint at the source points will reduce the solids content of effluent, reduce sulfur and other contaminants that can be generated from anaerobic decomposition of natural fibers, and also reduce the frequency of sewer obstructions. Recovered fibers will increase the amount of solid wastes unless they can be reused or sold.

For Further Information

For further information on this assessment or other activities sponsored by EP3, call the EP3 Clearinghouse at (703) 351-4004, send a fax to (703) 351-6166, or on Internet apenderg@habaco.com.

HBI-94-012, Pub. 09/30/94

OTHER CASE STUDIES

CASE STUDY #1

Company:	Rexham Corporation
Location:	City of Matthews (Mecklenburg County)
Product:	Paper, Film and Foil Products
Description:	Rexham has developed a comprehensive waste management program incorporating several managerial and technical initiatives to reduce waste generation. For example, waste toluene from printing press cleanup has been eliminated by segregating the solvent according to the color and type of ink cleaned from the press. Each segregated batch of toluene is then reused for thinning the same type and color of ink. A carbon adsorption recovery system on the printing lines allows Rexham to capture and recover 90% of the toluene previously lost to the atmosphere. The recovered toluene is sold to the coating industry for use as a thinner at about one half the price of virgin solvent. Another major solvent waste stream containing methyl ethyl ketone is sent off-site for recovery and then reused by Rexham for cleanup operations.
Savings:	Rexhams's waste management program has reduced waste management cost as well as production costs. The sale of over 4500 tons per year of toluene captured by the carbon adsorption system realized a small financial return of 1 to 1½% The reuse of the waste toluene cleaning solvent reduced raw material costs and eliminated the cost of disposing of this waste stream.

CASE STUDY #2

Company:	Thiele-Engdahl, Inc.
Location:	City of Winston-Salem (Forsyth County)
Product:	Printing Inks
Description:	Thiele-Engdahl recovers and reuses spent isopropyl acetate generated during equipment cleanup. Solvent is used twice for equipment cleanup before being recovered. The solvent is reclaimed on-site using a batch distillation unit. The

distillation system processes two 55-gallon batches every 24 hours. The distillation bottoms are sent off-site for disposal.

Savings: Before the distillation system was installed, Thiele-Engdahl sent about 5,000 gallons of spent solvent off-site for disposal every 45 days. Reclaiming and reusing the solvents on-site significantly reduced this volume as well as the quantity of virgin solvents purchased. The savings are projected to fully cover costs for the distillation systems in 2 years.

CASE STUDY #3

Company: United Piece Dye Works

Location: City of Edenton (Chowan County)

Product: Textile Dye and Finishing

Description: United Piece Dye Works met stringent effluent discharge limits on phosphorous by making chemical substitutions in their production process rather than by building expensive treatment systems. A detailed evaluation of production processes, process chemistry, and the chemicals is used identified sources of phosphorous. Process modifications to reduce use of phosphate chemicals and substitution of non-phosphate containing chemicals were made. For example, the use of hexametaphosphate was reduced and the use of phosphoric acid was eliminated. A reduction in the level of phosphorus in the effluent from 7.7 mg/L to less than 1 mg/L was achieved through such modifications and chemical substitutions.

Savings: United Piece Dye Works met their effluent limits without any capital expenditure for phosphorous removal.

CASE STUDY #4

Company: Celanese Corporation

Location: City of Greenville, South Carolina

Product: Synthetic Fiber

Description: Celanese recovers and reuses two of its waste streams. Freon, used in the quality control laboratory, is recovered for reuse by a glassware batch distillation system. The still recovers most of the 4 gallons of waste solvent generated each week. Contaminated heat transfer fluid (Dowtherm) is sent to an off-site distillation facility for recovery and returned for reuse in production. Similar production prevention methods are used at Celanese plants in Salisbury and Shelby.

Savings: The recovery and reuse of Freon in the laboratory saves Celanese's Greenville plant over $1,800 a year in disposal and raw material costs. Recycling of heat recovery fluid saves the plant about $164,000 per year in disposal and raw material costs. Similar cost savings are realized by Celanese's two plants in North Carolina.

CASE STUDY #5

Company: American Enka

Location: Enka, NC

Product: Synthetic Fibers

Description: American Enka Company is a nylon yarn production and research facility. One of their processes uses isopropyl alcohol as a solvent for a fatty amine. The end product is a porous film of polymer. They previously employed an outside firm to distill their waste isopropyl alcohol. They then bought it back for reuse in their production line. Average distillation losses were 15%, but losses as high as 40% had occurred. Also, due to improper cleaning of the distillation column between runs, the isopropyl alcohol returned was often unusable due to contamination with Dowtherm, benzene, ethyl benzene, methyl benzene, various chlorinated hydrocarbons, and other organic constituents. Each batch of recycled isopropyl alcohol had to be analyzed for contamination, and, if found unsuitable, required disposal arrangements and fees.

Savings: To solve this problem, American Enka purchased a used distillation unit for $7,500 and modified it to redistill the isopropyl alcohol in-house. This resulted in a savings of $90,000/year, since it is less expensive to distill the alcohol on-site than to contract out these services. In addition, the in-house distillation is more efficient, recovering 90% of the isopropyl alcohol as opposed to the outside firm's efficiency of 85%. Not only does American Enka reuse the pure isopropyl alcohol the distillation unit produces, but they also utilize the still bottoms as an asphalt emulsifier in another product line. The payback period for this project was approximately one month.

CASE STUDY #6

Company: Ellen Knitting Mills

Location: Spruce Pine, NC

Product: Knit Fabric

Description: Ellen Knitting Mills, a Division of Hampshire Hosiery, was discharging spent dye bath water to the municipal sewer system. The temperature of the discharge water was 130 degrees F, which caused breakage of the terra cotta sewer piping. In 1981, the company invested $100,000 in a heat exchange system that lowered the effluent water temperature to 70 degrees F. Spent dye water is discharged into a holding vat from which it enters the stainless steel heat exchanger. The exchanger is composed of five 30-foot long 8-inch diameter pipes. Inside each pipe is a bundle of smaller tubes which allow the heat transfer.

Heat removed from the water is used to preheat incoming feed water for the dye tubs from 55 degrees F to about 105 degrees F. The preheating operation saves about 52,000 gallons of fuel oil per year, and the heat exchange system had a payback period of only two years.

The company made a second major modification which has also resulted in significant energy savings and reuse of waste materials. In 1982 Ellen Mills purchased and installed a sawdust fired steam generating plant for approximately $800,000. The units consists of a 12 ton receiving hopper, a conveyor transport system, a hogger, a 200 ton storage silo, a Dutch oven combustion chamber, an auxiliary oil burner, and a 400 horse power HRT boiler.

In the vicinity of Spruce Pine, North Carolina, there are several local sawmills and a ready supply of waste sawdust. The sawdust is trucked to the mill, where it is dumped into the receiving hopper, passed by conveyor belt under a magnet to remove metals, and passed on to a hopper where it is ground to a uniform size. The sawdust is then lifted by a bucket elevator to the top of the storage silo, which holds an 8 day supply of fuel.

Sawdust exits the silo from the bottom, where it is collected in a metering bin which dispenses it to a screw conveyor leading to the boiler. The metering bin has sensing devices to monitor the steam pressure in the boiler and releases sawdust as needed to maintain a constant pressure. The measured charge of sawdust is blown into the Dutch oven where combustion takes place. The heat produced by this combustion is introduced into the boiler where the steam is generated.

The exhaust gases pass through a series of cyclone separators to remove any particles and then into a smoke stack. At this point, a heat exchanger transfers heat from the exhaust and reinjects it under the grate in the combustion chamber. Since the mill has ample capacity in their dye house heat exchanger, they are using the preheated water as their boiler makeup water. This results in greater energy efficiency for the system.

Savings: The new boiler system has eliminated the need for the 300,000 gallons/yr of fuel oil. The sawdust fuel costs approximately $12.00/ton; the company reports a 66% savings on fuel costs. They estimate a payback period of only 4 years for the new system. The new boiler is also a much cleaner system since it is equipped with state-of-the-art pollution control devices. Cyclon separators scrub the vapors and prevent the particulate "fallout" that was present with the oil-fired steam generator.

APPENDIX II
TEXTILES EQUIPMENT VENDORS

Company	**Technology**	**Washing and Drying**	**Dyeing**	**Finishing**
Alsop Engineering Co. 321 Fair Street Kingston NY 12401 tel: (914) 338 0466 fax: (914) 3391063 Herbert Reeve or Bianci Quigley 1 800 336 0056	Agitators, fluid mixers, filters, pumps, mixers, stainless steel tanks, in a wide range of sizes. Portable mixers, air or electric. Three year warranty offered. Can augment older equipment. Also manufacture wastewater treatment equipment: line slurring floculation and suspended solid removal systems.	X	X	
Aztec Machinery Company 960 Jacksonville Road Ivyland, PA 18974 tel: (215) 672 2600 fax: (215) 441 0289	Thermal oxidizers			
Brinecell, Inc. 2109 West 2300 South Salt Lake City, UT 84119 tel: (801) 973 6400 fax: (801) 973 6463	Water treatment systems: Brinecell Model "302", "456" decolorize effluents in textile printing, finishing dyehouse plants, without using chemicals		X	X
B.F. Perkins 939 Chicopee ST Chicope, MA 01013-279 tel: (413) 536 1311 fax: (413) 536 1367	Nonwoven calendering systems Thermal and point bonding calenders			

Company	**Technology**	**Washing and Drying**	**Dyeing**	**Finishing**
Braun G.A. Inc. 1 800 ID Braun Contact: Martint of South Carolina. Jim Martin at (704) 573 1625	Laundry Systems: Full range of washers, dryers, finishing equipment, shuttle systems, monitoring and control systems and software. Computerized dye extractors. Wet and dry processes. Injection dyers. Center Shaft Injection Dyers. Slow speed tumblers. Networking for dye processes, Dyenet. Can do diagnostics and correct malfunctions online from U.S. office. Over thirty worldwide offices.	X	X	X
Consolidated Laundry Machinery Co. (Parent company is Rosco Machinery Co.) tel: (213) 232 2417 fax: (213) 231 8312	Laundering machinery, becks, squeeze dryers, washers/dryers			
Ensign Ribbon Burners tel: (914) 738 0600, (718) 324 1345 fax: (914)738 0928	Singeing equipment. Ribbon Pipe Burners Water Cool Burners. Will be able to supply monitoring and control systems (automated) soon.			X

Company	Technology	Washing and Drying	Dyeing	Finishing
Entec Industries Inc. P.O. Box 5511 Greenville, SC 29606 tel: (803) 277 6361 fax: (803) 299 9818	Drying machines "Knife Over Roll Coaters" "Nip and Dip Coaters" Gravure Coaters Laboratory Coaters Powder Applicators Flocking Machines lead in and exit machines Thermal Bonding: Stretch Roll Machine Incline Tenter			X

Company	Technology	Washing and Drying	Dyeing	Finishing
EVAC Corporation A Subsidiary of Kusters Corp. USA Zima Park DR P.O. Box 3274 Spartanburg, SC 29304-3274 tel: (803) 576 0660 fax: (803) 439 8211	Vacuum extraction systems: EVAC Water Removal System DYEVAC System Lint Removal System Wet-on-Wet Finishing System UltraKnit Mark III Tensionless Processor Stage Washer System	X		X
Fab-Con, Inc. P.O. Box 423 Harrisburg, NC 28075-0423 tel: (704) 455 3999 contact: Chris Snyder Fab-Con Machinery Development Corp. P.O. Box 591 75 Channel DR Port Washington, NY 11050-2216 tel: (516) 883 3999 fax: (516) 883 3880	"Versa-Tenter" incinerator - reduction of particle emissions	X		

Company	Technology	Washing and Drying	Dyeing	Finishing
Forte Technology, Inc. 201 Carnegie Row Norwood, MA 02062 tel: (617) 769 9150 fax: (617) 769 5308	Moisture Monitoring Systems Moisture Control 7590 - yarn, small objects Moisture Control 2590 - bales of staple fiber Moisture Control 3790 - for special measurements made in bale process - correspond with IWTO Spec 41 (International World Trade Organization specifications)		X	
Gaston County Dyeing Machine Co. P.O. Box 308 Stanley, NC 28164 tel: (704) 822 5000 fax: (704) 882 0753 Contact: Ted Higley, International Marketing Director	Dye equipment. Bleaching, dyeing, dryers for fabrics, apparel, cotton, gauze, thread and yarn. Full line of Jet dyers (Gaston AT). Able to supply full field support, technical support including technical engineers. Computerized control and monitoring systems. Dyers from 180 kg/ load to 2000 kg/ load.	X	X	X

Company	Technology	Washing and Drying	Dyeing	Finishing
Martint Equipment Co. 4455 Morris Park DR Suite B Charlotte, NC 28227 tel: (704) 573 1625 fax: (704) 573 1725	"UniMac": automatic dyeing/extracting machine G.A. Braun products: dye extractors, scour bleach machines, dryers KEMCO products: waste water heat recovery systems		X	
Mascoe Systems Corporation Box 370 Maudlin, SC 29662 tel: (803) 277 3246 fax: (803) 299 3183	Drying Machines: Mascoe 886 Levitator Tenter Dryer (40 ft.) $800,000 plus an EAS 4,000 air scrubber $200,000 - air scrubber has 5% emission rate Foaming Units "FR 31 Foamer" "FR 45 Foamer" $45,000 each - chemical waste reduction of 60% - replace existing foamers which use 30-50 gallons, these foamers use 2-3 gallons Coating Machines - currently do not export due to large domestic demand, but are willing to export anywhere but Korea and India	X	X	

Company	Technology	Washing and Drying	Dyeing	Finishing
Morrison Textile Machinery Co. P.O. Drawer 1 Fort Lawn, SC 29714 Ford, Elliot & Trimble, Inc. 1009 East BLVD Charlotte, NC 28203 tel: (704) 335 1617 fax: (704) 335 1825	"Incline Model I Washer" "Incline Model II Washer" Z-80 Washer (same result as Incline Washers, but different approach) (working on recovery of water process, reduction of effluent, removal of sizing and caustic soda)	X		
Morton Machine Works, Inc. P.O. Box 2547 Jackson AVE Columbus, GA 31902-2547 tel: (706) 322 5541 fax: (706) 322 0497	Heat recovery systems: shell and tube heat exchangers Morton offers Seven Point Plan for energy conservation through machine and process improvements and waste heat recovery drying systems: high pressure blower - cuts normal drying cycles by one-half control systems: Morton Control Systems (Input and Output modules are available). "Master Dyer" software "Advantage" Supervisory Software "Stand Alone" Controller - PLC based	X	X	X

169

Company	**Technology**	**Washing and Drying**	**Dyeing**	**Finishing**
Osmonics 5951 Clearwater Drive Minnetonka, MN 55343-8990 tel: (612) 933 2277 fax: (612) 933 0141	Water Purification Systems			
Pellerin Milnor Corp. tel: (504) 467 9591 ext. 222	Washing, extracting, scourning, stone washing, fulling and dyeing	X	X	
Precision Machine & Development Co. tel: (302) 328 1511 fax: (302) 328 1954 DuPont Product Information Center (302) 774 1000.	Air Texturing Jet. Taslan Jet, DuPont trademark. Texturing jet. Compressed air system. Technical assistance available.			X
Scholl America 4420Taggart Creek Road Charlotte NC 28208 tel: (910) 449 2000 fax: (910) 392 4444 (sales) Contact: John Norris tel: (704) 392 5200	Dye equipment. Completely automated plant design. Dye systems automated. Will be able to fully automate plant from database, material handling, scheduling etc.			X
Strandberg Engineering Co. 1302 N. O'Henry Blvd. Greensboro NC 27405 tel: (910) 274 3775 fax: (910) 272 4521	Moisture Monitoring Systems Dry Stop Model M-702 Dry Stop Model M-702a Moisture Monitor Model 1603		X	

Company	**Technology**	**Washing and Drying**	**Dyeing**	**Finishing**
Tubular Textile Machinery Hargrave RD P.O. Box 2097 Lexington, NC 27293-2097 tel: (704) 956 6444 fax: (704) 956 8956	"Tube-Tex Dyrol": cold batch dyeing in tubular form "Automatic Batcher" "Four Roll Pad": squeezing machine that uses less chemicals than others - extracts water, applies chemicals		X	
Unimac Co. Inc. tel: 1 800 343 1116 fax: (904) 526 1509	Laundry systems for dyeing		X	
Utica Mill Specialty Machinery Co. Inc. tel: (315) 736 3030 fax: (315) 736 2909	Dyeing and finishing. cutting, sewing, extractor loader/unloader, tubular knit fabric turner, old style calender system		X	X

Table 1: Summary of Recommended Pollution Prevention Opportunities

Unit Operation	Pollution Prevention Action and Environmental/ Product Quality Benefit	Cost	Financial Benefit	Payback Period
	First Priority Opportunities			
Steam Traps	Repair leaking traps - reduces air emissions and fuel costs.	$700 to replace traps.	$47,000 per year	1 week
Steam System	Evaluate steam system components and layout and add at least two steam traps - reduces energy use prolongs life of components and reduces bath and boiler water contamination.	$120 for insulation;$500 for traps.	To be determined	To be determined
Steam Traps	Improve knowledge of steam trap selection - reduces energy use and avoids purchase and repair of traps.	None	To be determined	Immediate
Steam Traps	Purchase and use steam leak detector - reduces fuel consumption.	$1100 for instrument	To be determined	To be determined
Dyeing Becks	Modify rinsing procedures and becks - reduces water costs.	$400 for 16 valves flow restrictors and siphon piping.	$45,000 per year	Less than 1 week
Dye Baths	Replace sodium sulfate with sodium chloride - reduces sulfate emissions below effluent standards and reduces chemical costs.	None	$7,500 per year	Immediate
Wool Laundries	Repair leaks - reduces water and energy use.	$50 for screens and valve.	$3,700 per year	Less than 1 week
Zonco Washer	Repair leaks and maintain drain valves - reduces water and energy use.	None	$2,200 per year	Immediate
Sulfuric Acid Decarbonizing	Filter acid continuously - reduces release of sulfuric acid to sewer system.	$700 for in-tank filter.	$300 per year	2.5 years
Floor Drains	Install and maintain screens to prevent lint from entering drains - reduces suspended solids sedimentable solids and sulfide in effluent.	$10 for screens.	To be determined	To be determined
Beck Number 10	Relocate steam coil to prevent boil-over - reduces loss of chemicals and energy to drains.	None	To be determined	Immediate
All Becks	Repair and maintain steam coils - reduces fuel consumption and prevents contamination of dye baths and boiler water.	None	To be determined	Immediate
Boiler	Purchase and install combustion controls - reduces emissions and fuel use.	Unquantified	To be determined	Immediate
Jet Dyers	Monitor dye bath temperature to detect out-of-control condition - avoids chemical loss to sewer and reduces energy use.	$25 for thermometers.	To be determined	To be determined
Dyeing Process	Use Datacolor instrument to control process - reduces chemical use.	None	To be determined	Immediate
EMOS Water Supply	Test plant water distribution system for leaks - reduces water use.	None	To be determined	Immediate
Green Dryer	Re-balance internal air flow - reduces emissions of H_2SO_4 mist and energy use.	None	To be determined	Immediate
Green Dryer	Install exhaust fan after re-balancing dryer - avoids worker exposure to sulfuric acid mist and future medical costs.	$700 (est.)	To be determined	To be determined
Sewer Effluent	Determine nitrogen and hydrocarbon concentrations - assures compliance with effluent standards and helps set reduction priorities.	$200 for testing.	To be determined	To be determined
TOTALS		$4,500	At least $105,700 per year	

Figure 1: Cotton and Polyester Processing

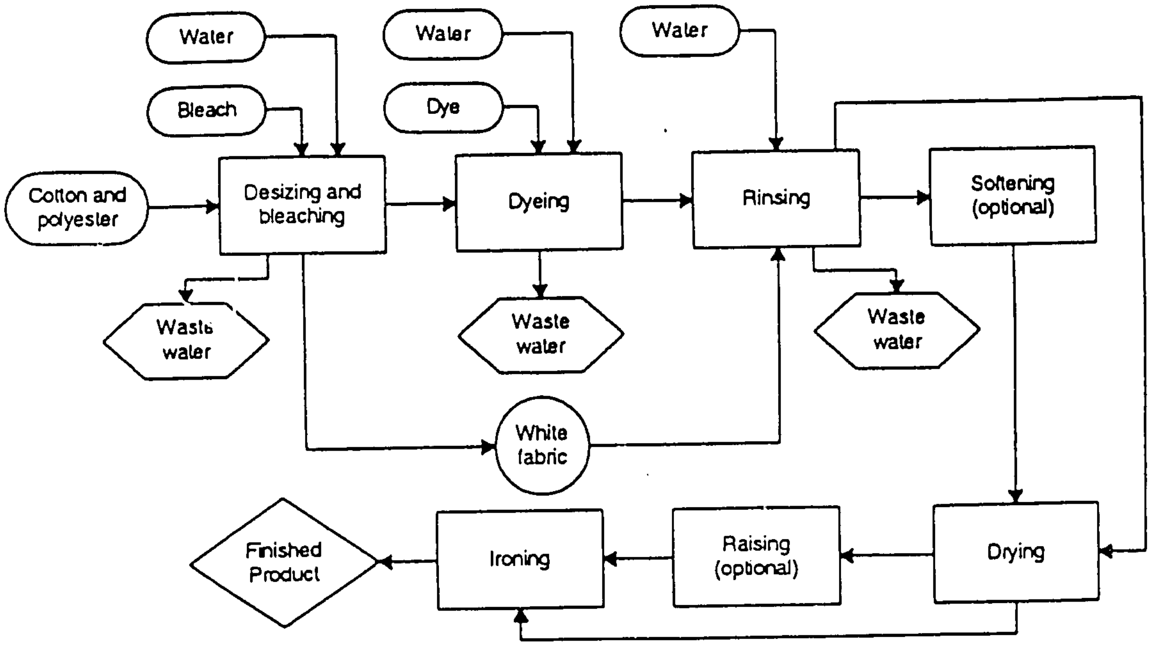
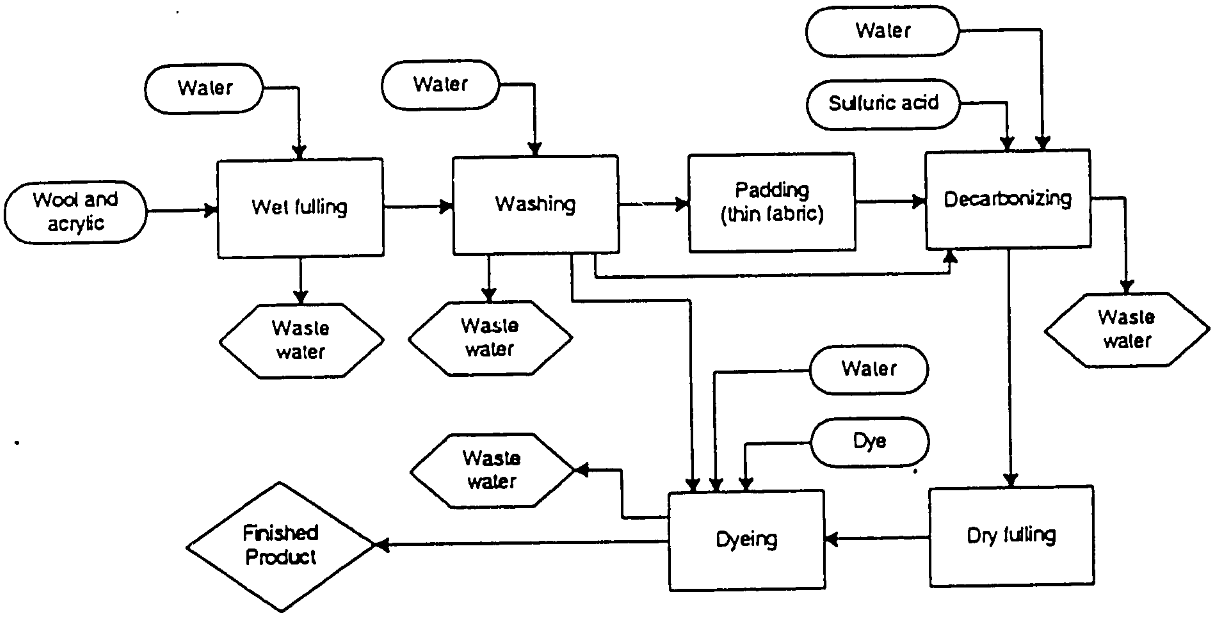


Figure 2: Wool and Acrylic Processing



boiling water to improve appearance and brightness), and (3) dyeing. For detailed depictions of these processes, see Figure 2.

White fabric is desized and bleached in becks, with nominal capacities of 500 liters, 1,000 liters, and 1,500 liters of water. Fabrics to be dyed are desized and then dyed in jets.

Existing Pollution Problems

At the time of the assessment, there were a number of pollution problems at the facility, including (1) excessive loss of water, chemicals, and heat energy from the becks, (2) excessive use of water in the rinsing process due to residual solution left at bottom of the beck, (3) excessive suspended solids, primarily