Industrial Water Conservation
References of Textile Manufacturers and Dyers

California Department of Water Resources
The Resources Agency

The Metropolitan Water District
of Southern California

1989
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Textile Manufacturers
and Dyers

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1989

Compiled by Brown & Caldwell
Consulting Engineers
Pleasant Hill, California
INDUSTRIAL WATER CONSERVATION REFERENCES OF TEXTILE MANUFACTURERS AND DYERS

FOREWORD

In 1987 the Department of Water Resources and The Metropolitan Water District of Southern California sponsored a literature search for technologies that can save water in those California industries which use the largest amounts of water. A bibliography of informative articles on water conservation in each industry was prepared. This report deals with the textile industry.

We have published in separate documents the bibliographies and selected articles for several other industries. These include:

- Food Processing
- Beverage and Bottling
- Paper and Packaging
- Laundry
- Electroplating
- Auto Manufacturing

In the future the Department of Water Resources will visit selected industrial sites and quantify the water savings achieved in several manufacturing processes. Water saving methods that are shown to be cost effective will be offered to manufacturers statewide through cooperative programs with local water agencies.

To obtain further information on industrial water conservation measures or DWR’s program, phone (916) 323-5580, or write:

Department of Water Resources
Office of Water Conservation
P.O. Box 942836
Sacramento, CA  94236-0001

To obtain a free copy of this report and other reports in this series, write to DWR’s Central Records Office at the same address.

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OVERVIEW OF WATER-SAVING TECHNOLOGIES</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>BIBLIOGRAPHY</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>References to Articles by Industrial Sector and Conservation Process</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>TRANSFERABILITY OF CONSERVATION TECHNIQUES</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>SELECTED ARTICLE</td>
<td>29</td>
</tr>
</tbody>
</table>

**Development Document for Effluent Limitations Guidelines and Standards for the Textile Mills Point Source Category**, Publication Number U.S. EPA 440/1-82/022, September 1982, excerpts from Section VII, Control and Treatment Technology, pages 231-238. (Reproduced with permission from the U.S. Environmental Protection Agency.)
CHAPTER 1 -- OVERVIEW OF WATER-SAVING TECHNOLOGIES

Water conservation can increase the profits of industrial facilities and conserve California's water resources. Conserving water used for processing and landscaping can reduce the costs for water supplies, electric power for pumping, water heating, chemicals for water treatment, and waste discharge to municipal treatment systems. Other benefits include favorably influencing public opinion about stretching water supplies and improving waste water quality for discharge requirements. Any one of these benefits and cost reductions may be worth more than the cost of the water alone. Managers for industries and water agencies need to be aware of water conservation potential so they can help their organization realize the benefits.

The literature search yielded 10 articles on water conservation in the textile manufacturers and dyers industry.

Examples of textile manufacturers and dyers found in this study include manufacturers of broadwoven fabric, man-made fibers, silk, knitting mills, and floor covering mills. This industry's incentive to conserve water results from the high concentrations of organics and auxiliary organic chemicals in its industrial effluents. Treatment of these constituents can be costly; thus, reducing wastewater is an important concern.

Water conservation practices covered in the articles ranged from recycling and reuse to advanced treatment processes such as reverse osmosis. Most of the reviewed articles discussed the reuse and recycling of the liquid wastes from dyeing processes. This dye process emphasis is not surprising considering that fabric and yarn dyeing constitutes the majority of a mill's water use.

A good overview of the textile industry and its use of water is the U.S. Environmental Protection Agency publication, Development Document for Effluent Limitations Guidelines and Standards for the Textile Mills Point Source Category, from which excerpts can be found reprinted in Chapter 4.

The two major water reuse measures available to textile mills are:

(1) Reuse uncontaminated cooling water in operations requiring hot water.

Examples are of uncontaminated, non-contact cooling water are:

- Condenser cooling water
- Water from water-cooled bearings
- Heat-exchanger water
- Cooling roll water
o Yarn dryers
o Pressure dyeing machines
o Air-compressors

This water can be pumped to hot water storage tanks for reuse in operations such as:

o Dyeing
o Bleaching
o Rinsing
o Cleaning

(2) Using the waste stream of one process as makeup water in another, chemically-compatible process.

o Bergenthal (see article 2) discusses how repeated reuse of dyebaths for carpet dyeing can reduce water, chemical, energy and sewer costs by 25-50 percent. The full scale demonstrations showed that up to 10 dyeings could be performed with recycled dye liquor without affecting product quality. The cost savings result in a short payback period, generally less than two years.

o Dyebath color removal by advanced treatment methods such as ozone oxidation is also examined, notably by Cox (see article 4). Some of the findings from this study were that through reuse and treatment by ozonation:

1. Wastewater can be reused a minimum of twenty times.
2. No wastewater discharge was incurred.
3. There was 75 percent reduction in chemical costs.
4. Energy savings were good (e.g., 60 percent reduction in heating).

These decolorized processes are especially useful since their waters can be recycled for use in dyebaths of any color. Both methods of dyebath reuse preserve the quality of auxiliary dyebath chemicals, leading to substantial chemical cost savings as well.
CHAPTER 2 -- BIBLIOGRAPHY FOR THE
TEXTILE MANUFACTURING AND DYEING INDUSTRY

This chapter contains a bibliography of articles on water conservation in the textile manufacturing and dyeing industry.

Two reference tables following the bibliography will help readers select the articles most appropriate to their needs. Table one references articles by industrial sector and table 2 references articles by conservation process.

One of the articles listed in the bibliography is reproduced in Chapter 4. Other articles may be obtained from libraries, industrial associations, and the original publishers. Additional references may be gleaned from the WaterNet of the American Water Works Association and NTIS data base systems, journals, and conference proceedings.


<table>
<thead>
<tr>
<th>Textile Manufacturing and Dyeing Sector</th>
<th>Article Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nylon carpet</td>
<td>7</td>
</tr>
<tr>
<td>Polyester</td>
<td>7</td>
</tr>
<tr>
<td>Rope bleaching</td>
<td>5</td>
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</table>
TABLE 2

REFERENCE TO ARTICLES BY CONSERVATION PROCESS

<table>
<thead>
<tr>
<th>Process or Topic</th>
<th>Article Number</th>
</tr>
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<tbody>
<tr>
<td>Batch dyeing</td>
<td>1, 2, 7</td>
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<tr>
<td>Biological treatment</td>
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<tr>
<td>Chemical treatment</td>
<td>6</td>
</tr>
<tr>
<td>Coagulation</td>
<td>6</td>
</tr>
<tr>
<td>Continuous range dyeing</td>
<td>1</td>
</tr>
<tr>
<td>Countercurrent</td>
<td>*8</td>
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<tr>
<td>Dye bath reuse</td>
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<tr>
<td>Economics of water conservation</td>
<td>1</td>
</tr>
<tr>
<td>Energy savings from water conservation</td>
<td>4, 5</td>
</tr>
<tr>
<td>Excited singlet oxygen treatment</td>
<td>7</td>
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<tr>
<td>General Conservation</td>
<td>*8</td>
</tr>
<tr>
<td>In plant controls</td>
<td>*8</td>
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<tr>
<td>Material reclamation</td>
<td>*8</td>
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<tr>
<td>Ozonation</td>
<td>4, 7</td>
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<tr>
<td>Process changes</td>
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<tr>
<td>Recycling</td>
<td>1, *8</td>
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* Article reprinted in Chapter 4.
REFERENCE TO ARTICLES BY CONSERVATION PROCESS

<table>
<thead>
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<th>Process or Topic</th>
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<td>Reuse</td>
<td>1, 2, 4, 5, 7, *8</td>
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<tr>
<td>Reverse osmosis</td>
<td>3, 6</td>
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<tr>
<td>Wastewater savings through water conservation</td>
<td>4, 5</td>
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<tr>
<td>Zero discharge</td>
<td>6</td>
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</tbody>
</table>

* Article reprinted in Chapter 4.
Conservation measures may apply to several sectors of the textile manufacturers and dyers industry. For example, a cooling water may be reused in almost every sector. Dyebath recycling techniques from the carpet sector may be transferable to other sectors using dyebaths. Because of the direct transferability among sectors, we have included articles that discuss general conservation practices in the textile manufacturers and dyers industry.

Water conservation measures may also be transferred among industries. Efficient cooling system designs are valuable in any industry using large volumes of water for cooling purposes. Table 3 cross references conservation measures that are transferable among several industries. For example, the table shows that reuse of non-contact cooling water, prevalent in the textile and dyes industry, would also be appropriate for the textile manufacturers and dyers industry.
<table>
<thead>
<tr>
<th>Selected conservation measure</th>
<th>Food processing</th>
<th>Paper &amp; packaging</th>
<th>Textile &amp; Dyes</th>
<th>Laundries</th>
<th>Hospitals</th>
<th>Electro Plating*</th>
<th>Auto Manufacturers</th>
<th>Beverage bottlers &amp; brewers</th>
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<tr>
<td>Recycling and reuse with advanced treatment</td>
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<tr>
<td>Automatic shut-off valves</td>
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<td>Air cooling instead of water cooling</td>
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<td>●</td>
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<tr>
<td>Reclaimed water for cooling</td>
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<td>●</td>
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<td>Efficient low-water using peelers</td>
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<td>●</td>
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<td></td>
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<td>●</td>
<td>●</td>
<td>●</td>
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</tbody>
</table>
CHAPTER 4 -- SELECTED ARTICLE

This chapter contains one informative article on water conservation in the textile manufacturers and dyers industry. The article is:

Development Document for Effluent Limitations Guidelines and Standards for the Textile Mills Point Source Category, Publication Number U.S. EPA 440/1-82/022, September 1982, excerpts from Section VII, Control and Treatment Technology, pages 231-238. (Reproduced with permission from the U.S. Environmental Protection Agency.)
DEVELOPMENT DOCUMENT
for
EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS
for the
TEXTILE MILLS POINT SOURCE CATEGORY

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September, 1982

Effluent Guidelines Division
Office of Water
U.S. Environmental Protection Agency
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SECTION VII
CONTROL AND TREATMENT TECHNOLOGY

This section describes the control and treatment technologies that are in use and available to reduce the discharge of pollutants from textile mills. There are two major technology approaches available: 1) in-plant controls and process changes and 2) effluent treatment technology. Programs combining elements of both approaches are applicable to many mills in the industry. Both approaches should be considered to determine which specific combination is best suited to a particular facility.

In-plant controls and process changes reduce hydraulic and pollutant loadings originating from mill operations. Although their use for pollutant reduction has been limited, greater attention is now being given to them because of economic and energy considerations.

Considerable research has taken place on the various effluent treatment technologies applicable to textile mills. Over 80 percent of the direct discharging mills in the industry provide wastewater treatment. Similarly, over 40 percent of the indirect discharging mills provide wastewater treatment before discharging to POTWs. Preliminary treatment, biological treatment, chemical treatment, physical separation and sorption systems applicable to textile industry wastewater are described following the discussion of in-plant controls. In addition to the description of each treatment method, detailed information on application of the method in the textile industry and its effectiveness is presented.

IN-PLANT CONTROLS AND PROCESS CHANGES

It is often more efficient to control pollution at its source, i.e., to prevent the generation of waste, rather than to depend on treatment to reduce or remove it. For this reason, an investigation of in-plant controls and process changes that might be instituted to reduce the strength or volume of wastewaters is a logical first step in any pollution control program. Conscientious implementation of in-plant controls and process changes can be effective in reducing water use and pollutant discharges.

For discussion purposes, in-plant measures have been divided into five types: 1) water reuse, 2) water use reduction, 3) chemical substitution, 4) material reclamation and 5) process changes and new process technology. Water reuse and water use reduction modifications result in a lower hydraulic loading on existing treatment facilities that in turn yield an improved effluent quality because of increased detention time. For new facilities,
smaller treatment units may be used, involving less capital and lower operating costs. Chemical substitution and material reclamation can be used to reduce toxic, nonconventional and conventional pollutant loadings on treatment facilities. Process changes and new process technology can result in water and pollutant reductions through improved process control and operating efficiency.

**Summary of In-Plant Controls Data**

The Agency received surveys from 541 textile mills during the initial phase of this study. Of these, 152 provided relevant information about the use of in-plant process control. In some instances, this information was supplemented by telephone discussions with knowledgeable mill personnel. A summary of the responses, reported by subcategory, is provided in Table VII-1. The number of controls cited by the 152 mills totaled 195, or 1.3 controls per mill. Approximately 47 percent are water reuse measures, 23 percent are process water reduction measures, 19 percent involve substitution of process chemicals and 11 percent involve reclamation of process chemicals.

**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.

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.
<table>
<thead>
<tr>
<th>Subcategory</th>
<th>Water Reuse</th>
<th>Water Use Reduction</th>
<th>Chemical Substitution</th>
<th>Material Reclamation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Wool Scouring</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2. Wool Finishing</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>4. Woven Fabric Finishing</td>
<td>28</td>
<td>20</td>
<td>17</td>
<td>16</td>
<td>81</td>
</tr>
<tr>
<td>5. Knit Fabric Finishing</td>
<td>24</td>
<td>8</td>
<td>9</td>
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<tr>
<td>Fabric Processing</td>
<td></td>
<td></td>
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<td></td>
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<td>Hosiery Processing</td>
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<td>1</td>
<td>0</td>
<td>2</td>
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<tr>
<td>6. Carpet Finishing</td>
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<td>2</td>
<td>3</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>7. Stock &amp; Yarn Finishing</td>
<td>21</td>
<td>9</td>
<td>3</td>
<td>1</td>
<td>34</td>
</tr>
<tr>
<td>8. Nonwoven Manufacturing</td>
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<td>1</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>9. Felted Fabric Processing</td>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
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<tr>
<td>All Subcategories</td>
<td>92</td>
<td>45</td>
<td>36</td>
<td>22</td>
<td>195</td>
</tr>
</tbody>
</table>

Ninety-two mills of the 541 mills in the survey reported some form of water reuse. The most common item is the reuse of cooling water to heat process water. Temperature increases as great as 33°C (91°F) were reported. Most mills in the survey that reported the reuse of cooling water began the practice in the mid-seventies to conserve energy. At some mills, both energy and water savings were major considerations in instituting reuse. Energy savings were reported ranging from 252 million to 25.2 billion kilogram-calories (1 billion to 100 billion Btu/yr), while water savings varied from 9.5 to 380 cu m/d (2,500 to 100,000 gpd) or more. Costs to institute water reuse measures ranged from less than $5,000 to more than $50,000 at some facilities. The principal cost items were pumps, piping modifications and hot water storage tanks.

As the costs of energy and wastewater treatment increase, reuse of cooling water is expected to become more widespread in the industry. This is supported by the fact that many mills have reported current engineering studies in this area. The reuse of water from various textile processing operations also is practiced at a few mills and is being investigated at a number of others. Savings similar to those noted for cooling water reuse were reported and it is expected that more reuse of this nature also will become common.

Water Use Reduction

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 (17).

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, 45 mills have instituted water use reduction control measures. 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 mills. Energy and water savings can be substantial, but installation costs can vary considerably.

A few mills have reported that they 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.

Chemical Substitution

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 (18) 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."

Thirty-six mills reported that they had instituted chemical substitution as an in-plant control measure. Substitution for dyes requiring chromium mordants and chromate oxidizers are the most commonly cited. 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.

**Material Reclamation**

Material reclamation measures often are implemented to reduce processing costs, the reduction of pollutant loadings being a secondary benefit. As noted previously, caustic recovery after mercerizing is quite common, especially in large finishing operations. Recovery of various warp sizes has been investigated at length and shows promise. Size recovery was identified at three facilities; two mills reclaim PVA and one reclaim WP-50. While many carpet finishing mills segregate latex waste streams for treatment, only two segregate for recycle. Some mills reclaim scouring detergent or dye liquor for future batches. Reclamation of print solvent is practiced at one mill. In all, some form of material reclamation was noted at 22 mills. It is anticipated that chemical and wastewater treatment costs will make material conservation and recovery a more viable alternative in the future.

**Process Changes and New Process Technology**

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 (3).

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. It has been noted (19) that 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.