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Proposed

Textile Mills

Point Source Category

DEVELOPMENT DOCUMENT

for

PROPOSED EFFLUENT LIMITATIONS GUIDELINES, NEW SOURCE PERFORMANCE STANDARDS, AND PRETREATMENT STANDARDS

for the

TEXTILE MILLS POINT SOURCE CATEGORY

Douglas M. Costle
Administrator

Robert B. Schaffer
Director, Effluent Guidelines Division

John E. Riley
Chief, Wood Products and Fibers Branch

James R. Berlow
Project Officer

October, 1979

Effluent Guidelines Division
Office of Water and Waste Management
U.S. Environmental Protection Agency
Washington, D.C. 20460

ABSTRACT

This document presents the findings of an extensive study of the textile industry for the purpose of developing effluent limitations for existing point sources, standards of performance for new sources, and pretreatment standards for existing and new sources to implement Sections 301, 304, 306, and 307 of the Clean Water Act. The study covers approximately 6,000 textile manufacturing facilities in SIC Major Group 22 of which approximately 2,000 are specifically affected by the findings.

Effluent limitation guidelines are set forth for the degree of effluent reduction attainable through the application of the best available technology economically achievable (BAT) and the best conventional pollutant control technology (BCT), which must be achieved by existing point sources by July 1, 1984. The standards of performance for new sources (NSPS) set forth the degree of effluent reduction that is achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives. Pretreatment standards for existing and new sources (PSES and PSNS) set forth the degree of effluent reduction that must be achieved in order to prevent the discharge of pollutants that pass through, interfere with, or are otherwise incompatible with the operation of POTW.

The proposed regulations for BAT and BCT are based on the existing best practicable control technology (BPT) plus multi-media filtration or chemical coagulation and multi-media filtration, depending on subcategory. The proposed regulations for NSPS are based on biological treatment in the form of extended-aeration activated sludge plus chemical coagulation and multi-media filtration for all subcategories. The proposed regulations for PSES are based on preliminary treatment (screening, equalization, and/or neutralization as necessary for compliance with the prohibitive discharge regulations) plus chemical coagulation. The proposed regulations for PSNS are based on preliminary treatment of all wastes plus chemical coagulation and multi-media filtration of a segregated toxic pollutant waste stream. For Wool Scouring, the BAT, BCT, NSPS, and PSNS regulations are based on dissolved air flotation in place of multi-media filtration because of the nature of the suspended solids, while PSES is based on chemical coagulation combined with dissolved air flotation. Felted Fabric Processing BAT regulations are based on extended-aeration activated sludge.

Supportive data, rationale, and methods for develoment of the proposed effluent limitation guidelines and standards of performance are contained in this document.

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SECTION I

CONCLUSIONS

For the purpose of establishing wastewater effluent limitation guidelines for existing sources and standards of performance for new sources, the Textile Mills Point Source Category has been subcategorized as follows:

1. Wool Scouring
2. Wool Finishing
3. Low Water Use Processing
4. Woven Fabric Finishing
   a. Simple Processing
   b. Complex Processing
   c. Complex Processing Plus Desizing
5. Knit Fabric Finishing
   a. Simple Processing
   b. Complex Processing
   c. Hosiery Products
6. Carpet Finishing
7. Stock & Yarn Finishing
8. Nonwoven Manufacturing
9. Felted Fabric Processing

Raw materials, final products, manufacturing processes, and waste characteristics are interrelated in the textile industry and constitute the significant factors used in the subcategorization. Raw materials and final products form the basic framework, with the remaining factors, particularly the waste characteristics BOD_5, COD, and TSS, being reflected in the subcategories and subdivisions developed. Size, age, and location of facilities and plant operating characteristics were not found to constitute bases for subcategorization.

The most significant pollutants and pollutant parameters found in the wastewater in terms of occurrence and concentration for the industry in general include: 1) the conventional pollutants BOD_5, TSS, pH, and oil & grease (Wool Scouring only); 2) the nonconventional pollutants COD and color; and 3) the following toxic pollutants:

acrylonitrile
benzene
1,2,4-trichlorobenzene
2,4,6-trichlorophenol
parachlorometacresol
chloroform
1,2-dichlorobenzene
toluene
trichloroethylene
antimony
arsenic
cadmium
chromium
copper

ethylbenzene
trichlorofluoromethane
naphthalene
N-nitrosodi-n-propylamine
pentachlorophenol
phenol
bis(2-ethylhexyl) phthalate
tetrachloroethylene

cyanide
lead
mercury
nickel
selenium
silver
zinc

The pollutant parameters regulated by the proposed best conventional pollutant control technology (BCT) are BOD5, TSS, and pH.

The pollutants and pollutant properties regulated by the proposed best available technology economically achievable (BAT) and the new source performance standards (NSPS) are COD, TSS, total phenol, total chromium, total copper, total zinc, and color. NSPS additionally controls BOD5 and TSS serves as an "indicator pollutant" for toxic pollutant removal for both BAT and NSPS.

The pollutants regulated by the proposed pretreatment standards for existing and new sources (PSES and PSNS) are total chromium, total copper, and total zinc.

The wastewater from all subcategories are amenable to biological treatment and substantial removals of the significant conventional and non-conventional pollutants and pollutant parameters are being achieved by secondary biological treatment systems, particularly those employing extended-aeration activated sludge. Further end-of-pipe treatment by either multi-media filtration (dissolved air flotation for Wool Scouring) or chemical coagulation, or both, has been found to be the most cost-effective of the available technologies for controlling the discharge of toxic pollutants in this industry.

Total investment costs for all the proposed regulations (BCT, BAT, NSPS, PSES, and PSNS) are estimated to be $86 million. Associated annualized costs (including interest, depreciation, operation, and maintenance) are estimated to be approximately $40 million. Compliance with the regulations, assuming no increases in the price of textile goods, may result in as many as 39 plant closures (approximately 3 percent of the major wet-processing facilities). Associated with these potential closures would be loss of approximately 6,290 jobs (1.5 percent of the industry employment) and displacement of approximately 1.4 percent of total industry production.

The proposed regulations are not expected to seriously affect the rate of entry of new plants into the industry, nor slow considerably the rate of industry growth. Some of the displaced production may be absorbed by increased imports and the balance of trade may be affected as a result.

Compliance with the proposed regulations will lead to increases in energy requirements of from 0.02 to 0.5 percent for existing direct dischargers and 0.2 to 0.5 percent for existing indirect dischargers. For new sources, energy requirements are expected to increase from 1.3 to 2.0 percent for direct dischargers and 0.8 to 1.6 percent for indirect dischargers.

The proposed regulations also will result in a significant quantity of additional sludge being generated. This additional sludge, along with some of the existing sludge generation, is classified as hazardous waste under the Resource Conservation and Recovery Act (RCRA) and thus will have to be properly disposed of under RCRA regulations. The extent of this problem for the textile industry is currently being studied. No significant change in atmospheric quality in terms of air emissions, noise, or radiation are expected from implementation of the proposed regulations.

SECTION II

RECOMMENDATIONS

Based on the findings of this study, it is recommended that the wastewater effluent limitations attainable through the application of the best available control technology economically achievable (BAT) and the best conventional pollutant control technology (BCT) be based on the existing best practicable control technology (BPT), BPT plus multi-media filtration, or BPT plus chemical coagulation and multi-media filtration. For plants in the Woven Fabric Finishing (all subdivisions), Knit Fabric Finishing (except the Hosiery Products Subdivision), Carpet Finishing, Stock & Yarn Finishing, and Nonwoven Manufacturing subcategories, it is recommended that BPT plus multi-media filtration be the basis for the limitations. For plants in the Wool Scouring, Wool Finishing, and the Hosiery Products Subdivision of Knit Fabric Finishing subcategories, it is recommended that BPT plus chemical coagulation and multi-media filtration (dissolved air flotation in place of multi-media filtration for Wool Scouring) be the basis for the limitations. For plants in the Felted Fabric Processing Subcategory, it is recommended that extended-aeration activated sludge be the basis for BAT and BCT effluent limitations. The proposed limitations based on these criteria are presented in Tables II-1 and II-2.

It is recommended that the new source performance standards (NSPS) effluent limitations be based on biological treatment in the form of extended-aeration activated sludge plus chemical coagulation and multi-media filtration for all plants in all subcategories, except Wool Scouring in which dissolved air flotation is recommended in place of multi-media filtration and Low Water Use Processing in which the existing BPT technology is recommended. The proposed limitations based on these criteria are presented in Table II-3.

It is recommended that the pretreatment standards for existing sources (PSES) effluent limitation be based on preliminary treatment (screening, equalization, and/or neutralization as necessary for compliance with the prohibitive discharge pretreatment regulations) plus chemical coagulation. Dissolved air flotation is also included for Wool Scouring. The proposed limitations based on these criteria are presented in Table II-4.

It is recommended that the pretreatment standards for new sources (PSNS) effluent limitations be based on preliminary treatment of all wastes plus chemical coagulation and multi-media filtration of a segregated waste stream carrying a plant's toxic pollutants for all plants in all subcategories, except Wool Scouring in which dissolved air flotation is recommended in place of multi-media filtration and

Low Water Use Processing in which compliance with the prohibitive discharge pretreatment regulations is recommended. The proposed limitations based on these criteria are presented in Table II-4.

TABLE II-1
BAT and BCT*
EFFLUENT LIMITATIONS GUIDELINES**
AVERAGE OF DAILY VALUES FOR 30 CONSECUTIVE DAYS

Subcategory	BOD5	COD	TSS	Total Phenol	Total Chromium	Total Copper	Total Zinc	Color
1. Wool Scouring	0.9	24.6	6.3	0.001	0.006	0.006	0.01	1500
2. Wool Finishing	8.9	56.2	6.4	0.018	0.14	0.14	0.28	120
3. Low Water Use Processing#	0.7	-	0.7	-	-	-	-	-
4. Woven Fabric Finishing								
a. Simple Processing	1.6	22.6	2.0	0.003	0.04	0.04	0.08	220
b. Complex Processing	2.9	26.0	2.7	0.008	0.04	0.04	0.08	220
c. Complex Processing Plus Desizing	3.3	34.0	3.6	0.007	0.06	0.06	0.11	220
5. Knit Fabric Finishing								
a. Simple Processing	2.5	44.0	3.0	0.010	0.07	0.07	0.14	220
b. Complex Processing	2.3	28.0	2.9	0.006	0.04	0.04	0.08	220
c. Hosiery Products	3.1	32.5	4.0	0.003	0.03	0.03	0.07	120
6. Carpet Finishing	2.2	16.3	1.8	0.006	0.02	0.02	0.05	220
7. Stock & Yarn Finishing	1.4	16.8	1.6	0.008	0.05	0.05	0.10	220
8. Nonwoven Manufacturing	1.9	27.1	1.9	0.001	0.02	0.02	0.04	220
9. Felted Fabric Processing	13.4	97.0	36.0	0.03	0.11	0.11	0.21	240

* BCT limitations only consider BOD5, TSS, and pH. The limitations here are for plant production sizes that pass the BCT "cost-reasonableness" test. (See Section X.)

** Expressed as kg pollutant/kkg of product (lb/1000 lb) except for Wool Scouring, which is based on kkg of raw grease wool and color which is in ADMI units. (NOTE: pH is regulated under BCT and must be within the range of 6.0 to 9.0 at all times.)

\# Only subject to BCT limitations.

TABLE II-2
BCT*
EFFLUENT LIMITATIONS GUIDELINES**
AVERAGE OF DAILY VALUES FOR 30 CONSECUTIVE DAYS

Subcategory	BOD_5	TSS	pH
1. Wool Scouring	5.3	16.1	Within the range of 6.0 to 9.0 at all times for all subcategories
2. Wool Finishing	11.2	17.6	
3. Low Water Use Processing	0.70	0.70	
4. Woven Fabric Finishing			
a. Simple Processing	3.3	8.9	
b. Complex Processing	3.3	8.9	
c. Complex Processing Plus Desizing	3.3	8.9	
5. Knit Fabric Finishing			
a. Simple Processing	2.5	10.9	
b. Complex Processing	2.5	10.9	
c. Hosiery Products	8.7	16.0	
6. Carpet Finishing	3.9	5.5	
7. Stock & Yarn Finishing	3.4	8.7	
8. Nonwoven Manufacturing	2.5	5.4	
9. Felted Fabric Processing	13.4	36.0	

* BCT limitations only consider BOD_5, TSS, and pH. The limitations here are for plant production sizes that do not pass the BCT "cost-reasonableness" test. (See Section X.)

** Expressed as kg pollutant/kkg of product (lb/1000 lb) except for Wool Scouring, which is based on kkg of raw grease wool.

TABLE II-3
NSPS
EFFLUENT LIMITATIONS GUIDELINES*
AVERAGE OF DAILY VALUES FOR 30 CONSECUTIVE DAYS
ALL PLANTS

Subcategory	BOD5	COD	TSS	Total Phenol	Total Chromium	Total Copper	Total Zinc	Color
1. Wool Scouring	0.90	24.6	6.3	0.001	0.006	0.006	0.01	1500
2. Wool Finishing	8.9	56.2	6.4	0.018	0.14	0.14	0.28	120
3. Low Water Use Processing	0.70	1.4	0.70	-	-	-	-	-
4. Woven Fabric Finishing								
a. Simple Processing	0.74	15.5	1.4	0.002	0.04	0.04	0.08	120
b. Complex Processing	1.4	17.9	2.0	0.005	0.04	0.04	0.08	120
c. Complex Processing Plus Desizing	1.8	23.4	2.6	0.005	0.06	0.06	0.11	120
5. Knit Fabric Finishing								
a. Simple Processing	1.3	30.3	2.1	0.007	0.07	0.07	0.14	120
b. Complex Processing	1.1	19.3	2.1	0.004	0.04	0.04	0.08	120
c. Hosiery Products	3.1	32.5	4.0	0.003	0.03	0.03	0.07	120
6. Carpet Finishing	1.0	11.2	1.3	0.004	0.02	0.02	0.05	120
7. Stock & Yarn Finishing	0.63	11.6	1.1	0.005	0.05	0.05	0.10	120
8. Nonwoven Manufacturing	0.88	18.6	1.4	0.0006	0.02	0.02	0.04	120
9. Felted Fabric Processing	4.7	53.5	9.1	0.014	0.11	0.11	0.21	120

* Expressed as kg pollutant/kkg of product (lb/1000 lb) except for Wool Scouring, which is based on kkg of raw grease wool and color which is in ADMI units. (NOTE: pH must be within the range of 6.0 to 9.0 at all times.)

TABLE II-4
PSES AND PSNS
EFFLUENT LIMITATIONS GUIDELINES
AVERAGE OF DAILY VALUES FOR 30 CONSECUTIVE DAYS

Subcategory	Total Chromium (mg/l)	Total Chromium (kg/kkg)	Total Copper (mg/l)	Total Copper (kg/kkg)	Total Zinc (mg/l)	Total Zinc (kg/kkg)
1. Wool Scouring	0.50	0.006	0.50	0.006	1.00	0.012
2. Wool Finishing	0.50	0.14	0.50	0.14	1.00	0.28
3. Low Water Use Processing	Comply with prohibitive discharge pretreatment regulations					
4. Woven Fabric Finishing						
a. Simple Processing	0.50	0.04	0.50	0.04	1.00	0.08
b. Complex Processing	0.50	0.04	0.50	0.04	1.00	0.08
c. Complex Processing Plus Desizing	0.50	0.06	0.50	0.06	1.00	0.11
5. Knit Fabric Finishing						
a. Simple Processing	0.50	0.07	0.50	0.07	1.00	0.14
b. Complex Processing	0.50	0.04	0.50	0.04	1.00	0.08
c. Hosiery Products	0.50	0.03	0.50	0.03	1.00	0.07
6. Carpet Finishing	0.50	0.02	0.50	0.02	1.00	0.05
7. Stock & Yarn Finishing	0.50	0.05	0.50	0.05	1.00	0.10
8. Nonwoven Manufacturing	0.50	0.02	0.50	0.02	1.00	0.04
9. Felted Fabric Processing	0.50	0.11	0.50	0.11	1.00	0.21

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

The Federal Water Pollution Control Act Amendments of 1972 established a comprehensive program to "restore and maintain the chemial, physical, and biological integrity of the Nation's waters," [Section 101(a)]. By July 1, 1977, existing industrial dischargers were required to achieve "effluent limitations requiring the application of the best practicable control technology currently available (BPT)," [Section 301(b)(1)(A)]. By July 1, 1983, these dischargers were required to achieve "effluent limitations requiring the application of the best available technology economically achievable (BAT), which will result in reasonable further progress toward the national goal of eliminating the discharge of pollutants," [Section 301(b)(2)(A)]. New industrial direct dischargers were required to comply with Section 306, new source performance standards (NSPS), based on best available demonstrated technology. New and existing dischargers to publicly owned treatment works (POTW) were subject to pretreatment standards under Sections 307(b) and (c) of the Act. While the requirements for direct dischargers were to be incorporated into National Pollutant Discharge Elimination System (NPDES) permits issued under Section 402 of the Act, pretreatment standards were made enforceable directly against dischargers to POTW (indirect dischargers).

Although Section 402(a)(1) of the 1972 Act authorized the setting of requirements for direct dischargers on a case-by-case basis in the absence of regulations, Congress intended that, for the most part, control requirements would be based on regulations promulgated by the Administrator of EPA. Section 304(b) of the Act required the Administrator to promulgate regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of BPT and BAT. Moreover, Sections 304(c) and 306 of the Act required promulgation of regulations for NSPS, and Sections 304(f), 307(b), and 307(c) required promulgation of regulations for pretreatment standards. In addition to these regulations for designated industry categories, Section 307(a) of the Act required the Administrator to promulgate effluent standards applicable to all dischargers of toxic pollutants. Finally, Section 501(a) of the Act authorized the Administrator to prescribe any additional regulations "necessary to carry out his functions" under the Act.

The Agency was unable to promulgate many of these toxic pollutant regulations and guidelines within the time periods stated in the Act. In 1976, EPA was sued by several environmental groups and, in settlement of this lawsuit, EPA and the plaintiffs executed a

"Settlement Agreement," which was approved by the Court. This Agreement required EPA to develop a program and adhere to a schedule for promulgating, for 21 major industries, BAT effluent limitations guidelines, pretreatment standards, and new source performance standards for 65 "priority" pollutants and classes of pollutants. [See Natural Resources Defense Council, Inc. v. Train, 8 ERC 2120 (D.D.C. 1976), modified March 9, 1979.] On December 27, 1977, the President signed into law the Clean Water Act of 1977. Although this law makes several important changes in the federal water pollution control program, its most significant feature is its incorporation into the Act of many of the basic elements of the Settlement Agreement program for toxic pollution control. Sections 301(b)(2)(A) and (b)(2)(C) of the Act now require the achievement by July 1, 1984, of effluent limitations requiring application of BAT for "toxic" pollutants, including the 65 "priority" pollutants and classes of pollutants which Congress declared "toxic" under Section 307(a) of the Act. Likewise, EPA's programs for new source performance standards and pretreatment standards are now aimed principally at toxic pollutant controls. Moreover, to strengthen the toxics control program, Congress added a new Section 304(e) to the Act, authorizing the Administrator to prescribe what have been termed "best management practices (BMPs)" to prevent the release of toxic pollutants from plant-site runoff, spillage or leaks, sludge or waste disposal, and drainage from raw material storage associated with, or ancillary to, the manufacturing or treatment process.

In keeping with its emphasis on toxic pollutants, the Clean Water Act of 1977 also revises the control program for non-toxic pollutants. Instead of BAT for "conventional" pollutants identified under Section 304(a)(4) (including biological oxygen demand, suspended solids, fecal coliform and pH), the new Section 301(b)(2)(E) requires achievement by July 1, 1984, of "effluent limitations requiring the application of the best conventional pollutant control technology" (BCT). The factors considered in assessing BCT include the reasonableness of the relationship between the costs of attaining a reduction in effluents and the effluent reduction benefits derived, and the comparison of the cost and level of reduction for an industrial discharge with the cost and level of reduction of similar parameters for a typical POTW [Section 304(b)(4)(B)]. For non-toxic, nonconventional pollutants, Sections 301(b)(2)(A) and (b)(2)(F) require achievement of BAT effluent limitations within three years after their establishment, but not later than July 1, 1987.

The purpose of these regulations is to provide effluent limitations guidelines for BAT and BCT and to establish NSPS and pretreatment standards for existing and new sources (PSES, PSNS) under Sections 301, 304, 306, and 307 of the Clean Water Act.

METHODOLOGY

The data and technical findings presented in this document were developed by performing the following major tasks:

1. Collecting, reviewing, and evaluating existing information including: the administrative record; historical wastewater data from EPA regional offices, state water pollution control agencies, and municipalities; the literature; current research projects; and that available from textile trade associations.

2. Profiling the industry with regard to age, production, geographic location, type of discharge, raw materials, production processes, final products, in-plant controls, end-of-pipe treatment practices, and wastewater data.

3. Reviewing the existing industry categorization and developing a revised categorization to accommodate any previously unidentified segments of the industry.

4. Administering a screening sampling program to qualitatively determine which of the 129 toxic pollutants appear in textile industry raw wastewaters and treated effluents.

5. Developing, distributing, and retrieving a 308 data request (detailed survey questionnaire) to update the existing data base.

6. Administering a verification sampling program to confirm the presence of the toxic pollutants identified in the screening sampling, and to establish the effectiveness of in-place advanced treatment technologies in removing toxic pollutants.

7. Analyzing and organizing the data collected in each task area to establish an updated administrative record.

8. Establishing the alternative in-plant control measures and end-of-pipe treatment technologies that will result in the elimination or reduction of pollutant discharge from the industry.

9. Estimating the costs and effectiveness of the alternative control measures and treatment technologies for representative mills in each subcategory.

Evaluation of Existing Information

The collection, review, and evaluation of existing information was the initial major task performed. It provided the starting point for subsequent major tasks and established the extent of effort that was to be required in each. The review of literature and current research project reports continued throughout most of the project. A complete bibliography of the pertinent material reviewed is presented in Section XIV.

Profile of the Industry

Developing the profile of the textile industry required work in several of the major task areas. Following review of the existing profile information, it was recognized that a more current picture of the industry was necessary. The primary sources of information were the United States Department of Commerce Standard Industrial Classification (SIC) and the results of the 308 data request. Details of the data request are discussed below, and details of the industry profile are presented later in Section III.

Industry Subcategorization

A preliminary review of the existing industry subcategorization indicated that the basis for the subcategorization was not firmly documented. Consequently, a complete review of the industry for purposes of subcategorization was required. The information collected during the industry survey provided the data base for the review, and approaches based on the following were evaluated: 1) raw materials, 2) products, 3) manufacturing processes, 4) size, 5) age, 6) wastewater characteristics, 7) wastewater treatability, 8) non-water quality aspects, and 9) various combinations of the above. The results of the industry subcategorization are fully discussed in Section IV.

Screening and Verification Sampling

The wastewater sampling program required to characterize textile effluents with respect to the 129 toxic pollutants was performed in three phases. A fourth phase of sampling also was performed to evaluate the effectiveness of advanced treatment technologies in removing or reducing the levels of toxic pollutants.

The four phases of the program were conducted between March, 1977 and October of 1978, and involved a total of 50 mills. Field sampling teams composed of environmental engineers and environmental technicians performed the sampling. Engineers performed presampling visits to conduct a survey of each mill and made the necessary arrangements for the sampling crews. The samples collected were analyzed by either a private laboratory under contract to EPA or by one of several EPA laboratories.

The sampling and analytical procedures employed in all phases followed the "Sampling and Analysis Procedures for Screening of Industrial Effluents for Toxic Pollutants," U.S. EPA, Cincinnati, March, 1977, (revised April, 1977) and "Analytical Methods for the Verification Phase of the BAT Review," U.S. EPA Effluent Guidelines Division, Washington, D.C., June, 1977 (see Appendix D). Additional descriptions of the sampling program and a detailed discussion of the results are presented in Section V.

308 Data Request

The 308 data request (Industry Survey) was performed to update the existing data base. A master list of textile mills was developed by reviewing the Davison's Textile Blue Book (8). The mills were classified as "wet" or "dry" depending on the type of processing employed. Wet operations were further categorized based on product, raw materials, production processes, and type of processing equipment. The wet operations mills listed were sent an introductory letter during February, March, and April of 1977 that explained the purpose and nature of the survey. The letters were followed by a telephone survey performed by engineers assigned to the project. The availability of good historical wastewater monitoring data was established and basic mill information was obtained with the telephone survey.

A detailed data collection portfolio was designed and forwarded to each mill with available historical wastewater monitoring data. The returned portfolios were reviewed in detail and, when warranted, follow-up telephone calls were made to clarify or amplify the information. Distribution and review of the portfolios is discussed in more detail below under "Description of the Industry."

Data Analysis

The data collected as part of the evaluation of existing information, the 308 data requests, and the field sampling program were processed and fully analyzed. Most of the data were processed electronically. Information obtained from the 308 data requests provides the basis for the industry profile and the industry categorization. Historical wastewater monitoring data were used to establish typical raw waste and treated effluent characteristics for each subcategory. The field sampling results were used to characterize the wastewaters from each subcategory with respect to the toxic pollutants.

Data collected by the 308 data requests also provided a basis for evaluating the effectiveness of in-place treatment technologies and provided basic information related to design and cost of advanced treatment alternatives. The constituents of the wastewaters from each subcategory that should be subject to effluent limitations guidelines, new source performance standards, and pretreatment standards were established. The significance of the constituents is discussed in Section VI.

Control and Treatment Technology

The full range of in-plant controls and end-of-pipe treatment technologies that exist or are applicable for the wastewaters from each subcategory were identified. The data used for identification of the control and treatment technologies were derived from a number of sources including: EPA research information, published literature, various industry associations, qualified technical consultants, information furnished by individual textile firms and government agencies, and on-site visits including sampling programs and interviews at representative textile plants throughout the United States. The effectiveness of each control and treatment technology was established in terms of the amounts of constituents and the chemical, physical, and biological characteristics. The problems, limitations, and reliability of each treatment technology were also identified. In addition, the impacts of application of such controls or technologies on other problems, including air pollution, solid waste management, and energy were identified and the costs associated with the impacts estimated. The control and treatment information is discussed in detail in Section VII.

Costs

The treatment technologies recommended to remove or reduce the wastewater pollutants of significance from each subcategory were established, and the costs of application of these technologies for the full range of mills sized were estimated. The estimated costs represent a detailed analyses of the treatment requirements and were developed by selecting three or four model plants to represent the range of mills in each subcategory. The cost estimates and the basis for the estimates are fully detailed in Section VIII.

DESCRIPTION OF THE INDUSTRY

Background

The United States textile industries are covered by two of the twenty major groups of manufacturing industries in the Standard Industrial Classification (SIC). They are Textile Mill Products, Major Group 22, and Apparel and Other Textile Mill Products, Major Group 23. The Textile Mill Products group includes 30 separate industries that manufacture approximately 90 classes of products. The Apparel and Other Textile Products group includes 33 separate industries that manufacture some 70 classes of products.

The Textile Mill Point Source Category Development Document (1) covers those facilities in Major Group 22. These facilities are principally engaged in receiving and preparing fibers; transforming these materials into yarn, thread, or webbing; converting the yarn and web into fabric or related products; and finishing these materials at various stages of the production. Many produce a final consumer product such as thread, yarn, bolt fabric, hosiery, towels, sheets, carpet, etc., while the rest produce a transitional product for use by other establishments in Major Groups 22 and 23.

The facilities in Major Group 23, Apparel and Other Textile Mill Products, are principally engaged in receiving woven or knitted fabric for cutting, sewing, and packaging. Some of the products manufactured are dry cleaned and some undergo auxiliary processing to prepare them for the consumer. In general, all processing is dry and little or no discharge results.

General Profile of Major Group 22

Exact figures for the number of wet processing mills and the total number of mills in the textile industry are difficult to establish because of the relatively large numbers involved, the dynamic state of the industry, and differing classification criteria. Published reports first figure (wet processing) in the neighborhood of 2,000 mills, and the total mills between 5,000 and 7,500. The U.S. Department of Commerce Census of Manufactures (6) provided the most structured and inclusive information, and reports from the 1972 census were used in developing the general profile.

A breakdown of the Textile Mill Products group by SIC code (major product class) and region (geographical location) is provided in Table III-1. Nearly 80 percent of the facilities are located in the Mid-Atlantic and Southern regions. The remaining 20 percent are distributed about equally between the New England region and the North Central and Western regions. Some industries, particularly yarn manufacturing, weaving, and carpet manufacturing, are heavily concentrated in a few southeastern states.

The geographical distribution of mills is based in part upon historical considerations. The textile industry in this country began in the northeast and spread south due to that region's position as the major cotton producer. Although synthetics have replaced cotton as the primary material in recent years, the southeast continues to be the center of the textile industry.

General statistics regarding number of establishments, number of employees, and economics of manufacture are presented in Table III-2 for the Textile Mill Products group. Of the nine major product classes (three-digit SIC Codes), three have been subdivided to present

TABLE III-1
GEOGRAPHICAL DISTRIBUTION*
TEXTILE MILL PRODUCTS MAJOR INDUSTRIAL GROUP

Region	221	222	223	224	SIC Code 225	226	227	228	229	22
New England	14	56	71	111	101	110	22	102	242	829
Mid-Atlantic	52	104	64	124	1362	280	47	146	401	2580
South	223	231	32	111	1094	208	368	530	330	3127
N. Central & West	18	21	31	30	166	58	92	32	220	668
Total	307	412	198	376	2733	656	529	810	1193	7204

* Based on 1972 Census of Manufacturing (6)

Note:

New England - CT, MA, ME, NH, RI, VT
Mid-Atlantic - NJ, NY, PA
South - AL, AR, DE, FL, GA, KY, LA, MD, MS, NC, OK, SC, TN, TX, VA, WV
N. Central - IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, SD, WI
West - AK, AZ, CA, CO, HI, ID, MT, NM, NV, OR, UT, WA, WY

221 - Weaving Mills, Cotton
222 - Weaving Mills, Synthetic
223 - Weaving & Finishing Mills, Wool
224 - Narrow Fabrics Mills
225 - Knitting Mills (Incl. Finishing)
226 - Textile Finishing, Exc. Wool & Knits
227 - Floor Covering Mills
228 - Yarn & Thread Mills
229 - Miscellaneous Textile Goods
22 - Textile Mill Products

information for the industry segments that are of primary concern here and are likely to be most affected by the development of effluent limitations guidelines, new source performance standards, and pretreatment standards.

Knitting Mills (SIC 225) is the largest single major product class in terms of number of establishments with 38 percent. These mills employ 29 percent of all textile workers and the value of shipments is 27 percent of the industry total. Among specific industry segments, weaving mills, yarn & thread mills, finishing mills, and floor covering mills follow knitting mills in terms of number of establishments, number of employees, and value of shipments. The number of facilities manufacturing felt goods, nonwoven goods, and scoured wool is small relative to the rest of the industry. These three subdivisions combined accounted for less than 3 percent of the number of employees and value of shipments prior to 1972.

Water use and wastewater discharge statistics for the nine major product classes and subdivisions are provided in Table III-3. The Census of Manufactures report these statistics for only those establishments that discharge 75.7 million cubic meters (20 million gallons) per year or greater. Therefore, the numbers of establishments do not correspond between Tables III-2 and III-3. The values of shipments, which are provided in each table, give a good indication of the significance of the establishments covered in Table III-3. Of the nine major product classes, all except narrow fabric mills and knitting mills are composed of establishments whose value of shipments ranges from 45 to 77 percent of the values for all establishments in Table III-2. The average value of shipments for the facilities covered by Table III-3 is approximately 50 percent of the industry total, while the average number of establishments represents just over 10 percent of the total mills in the industry.

As a general summary it can be stated that based on the 1972 Census of Manufactures, the industries in Major Group 22 employ nearly one million persons and manufacture goods valued at over 28 billion dollars annually. In the process, they use and discharge over one-half billion cubic meters (130 billion gallons) of process-related wastewater each year.

Industry Survey

A major survey of the facilities in Major Group 22 was performed to provide a descriptive and representative data base from which subsequent decisions regarding effluent limitation guidelines, new source performance standards, and pretreatment standards could be made. The survey involved the following phases of activity: 1) developing a master list of textile mills thought to have wet production operations; 2) contacting mills on the master list by

TABLE III-2
GENERAL STATISTICS*
TEXTILE MILL PRODUCTS MAJOR INDUSTRIAL GROUP

Industry Segment	SIC Code	Establishments Total	Establishments 20+ emp.	Employees (1000's)	Value (10^6 \$/yr) Added by Manufacture	Value (10^6 \$/yr) of Shipments
Weaving Mills, Cotton	All Group No. 221	307	227	121.3	1256	2661
Weaving Mills, Synthetics	All Group No. 222	412	341	149.7	1832	3856
Weaving & Finishing Mills, Wool	All Group No. 223	198	119	19.4	239	450
Narrow Fabrics Mills	All Group No. 224	376	215	27.1	289	566
Knitting Mills (Inc. Finishing)	All Group No. 225	2723	1725	276.4	3180	7703
Hosiery Mills	2251, 2252	727	486	82.1	734	1585
All Other Knitting Mills	2253, 2254, 2257 2258, 2259	1996	1239	194.3	2446	6118
Finishing Mills, Exc. Wool & Knits	All Group No. 226	656	433	79.7	1120	2633
Broad Woven Fabric	2261, 2262	455	305	61.2	850	1996
Stock, Yarn, Narrow Fabric, etc.	2269	201	128	18.5	270	637
Floor Covering Mills	All Group No. 227	529	280	59.9	1078	3153
Yarn & Thread Mills	All Group No. 228	810	636	147.8	1586	4249
Miscellaneous Textile Goods	All Group No. 229	1193	529	71.5	1144	2802
Felt Goods	2291	47	30	5.0	80	146
Nonwoven Goods	2297	82	65	10.4	190	393
Wool Scouring & NEC# Goods	2299	345	79	8.3	108	212
Other Miscellaneous Textile Products	2292, 2293, 2294 2295, 2296, 2298	719	355	47.8	766	2051
Textile Industry - All Segments	Major Group No. 22	7204	4505	952.8	11724	28073

* Based on 1972 Census of Manufactures (6)
# NEC = Not Elsewhere Classified

TABLE III-3
WATER USE AND WASTEWATER DISCHARGE STATISTICS*
TEXTILE MILL PRODUCTS MAJOR INDUSTRIAL GROUP

Industry Segment	Establish-ments**	Value of Shipments (10^6\$/yr)	Water Use# (10^6 cu m/yr)	Wastewater Discharge Indirect (10^6 cu m/yr)	Wastewater Discharge Direct (10^6 cu m/yr)
Weaving Mills, Cotton	96	2058	35.2	22.0	26.9
Weaving Mills, Synthetics	113	2179	51.9	28.4	48.1
Weaving & Finishing Mills, Wool	32	277	22.0	11.4	13.6
Narrow Fabrics Mills	10	87	0.8	1.1	0.4
Knitting Mills (Including Finishing)	162	2357	88.9	84.8	25.7
Hosiery Mills	47	459	5.7	9.1	0.0
All Other Knitting Mills	115	1898	83.3	75.7	25.7
Finishing Mills, Except Wool & Knits	139	1852	169.6	78.3	105.2
Broadwoven Fabric	93	1463	141.9	53.0	100.7
Stock, Yarn, Narrow Fabric, etc.	46	389	27.3	25.4	4.5
Floor Covering Mills	65	1868	58.7	43.5	23.8
Yarn & Thread Mills	101	1907	39.0	30.7	27.6
Miscellaneous Textile Goods	70	1328	15.5	20.8	12.1
Felt Goods	7	64	1.5	0.8	1.5
Nonwoven Goods	10	140	4.9	2.3	3.4
Wool Scouring & Goods NEC##	13	74	3.8	3.4	2.3
Other Miscellaneous Products	40	1050	5.3	14.4	4.9
Textile Industry - All Segments	788	13913	481.6	321.0	283.4

* Based on 1972 Census of Manufactures (6)
** Only includes locations with greater than 7.5×10^4 cu m/yr discharge.
\# Process water not including recirculated flow.
\## NEC = Not Elsewhere Classified

letter to outline the purpose and intent of the survey; 3) contacting mills on the master list by telephone in order to assess the value of available wastewater information and to gather basic facility information; 4) distributing detailed survey questionnaires; and 5) retrieving and analyzing the questionnaires. Samples of the telephone and detailed survey questionnaires are placed in Appendix A.

In developing the master list of wet production facilities, consideration was given to several sources of information including the Standard Industrial Classification (SIC), the Census of Manufactures, data collected during previous textile industries studies, information from trade associations, and information in a commercial directory, "Davison's Textile Blue Book" (8). Examination of the various sources and knowledge gained from previous studies indicated that the directory provided the most useful and current information. It was reviewed and each facility listed was tentatively classified as wet or dry. Of 5,500 mills listed in the directory, approximately 2,900 were initially classified as dry and 2,600 were classified as wet. Wet operations were further subcategorized based on product, raw materials, production processes, and type of processing equipment. Information to identify each wet facility and to provide the means to make an initial contact was processed by computer, which in turn provided a master list.

A telephone survey of those mills classified as having wet manufacturing operations reduced the number of mills on the master list since many turned out to be dry operations or were no longer in the textile manufacturing business. Information on selected low water use mills was also received from a general survey. (See Appendix A for a sample of the survey questionnaire.) Detailed survey information for most wet manufacturing operations having available historical wastewater data. The information obtained from the surveys was recorded, and electronic data processing (EDP) was used to evaluate the results. This information provides the best general representation of the textile industry developed to date and serves as the basis of this report.

A breakdown of the 1,973 production facilities that comprise the master list is presented in Table III-4. The manufacturing segments listed resemble the recommended categorization of the industry for purposes of effluent limitation guidelines, new source performance standards, and pretreatment standards. There are 1,165 mills in the nine wet processing classifications and 808 mills classified as low-water-use-processing operations. Detailed survey information was received for 538 of the wet processing mills and an additional 573 provided general survey information. Actual confirmation of wet processing activities at the remaining 54 locations could not be made. Just over two-thirds of the wet processing facilities finish either woven or knit fabrics (including hosiery).

TABLE III-4
SURVEY STATUS SUMMARY - MILLS ON MASTER LIST

Manufacturing Segment	Total Mills Listed	Survey Status Detailed	General	No Contact
Wool Scouring	17	13	4	0
Wool Finishing	37	19	15	3
Low Water Use Processing	808	315	15	478
Woven Fabric Finishing	336	151	158	27
Knit Fabric Finishing	282	114	155	13
Hosiery Finishing	160	58	102	0
Carpet Finishing	58	37	18	3
Stock & Yarn Finishing	217	121	90	6
Nonwoven Manufacturing	38	14	23	1
Felted Fabric Processing	20	11	8	1
	1973	853	588	532

Stock and yarn finishing mills comprise nearly 20 percent of the wet processing facilities; wool goods processing, carpet manufacturing, and nonwoven manufacturing and felted fabric processing together each comprise approximately 5 percent. Detailed surveys provide information on more than one-third of the mills in each wet processing segment.

Low water use processing operations were surveyed separately from the wet processing mills; the 315 detailed survey responses noted were obtained from a random sample of approximately half of the mills initially classified as low water use operations.

The geographical distribution of the industry survey responses is shown in Table III-5. The distribution confirms observations made previously regarding Major Group 22. Over half of the wet production facilities are located in the southeast (EPA Region IV), particularly the Carolinas and Georgia. Another 25 percent are in the northeast (New England, New Jersey, and New York). Less than 5 percent of the mills are located in the west (EPA Regions VI through X).

Table III-6 illustrates the range of plant sizes (in terms of production exposed to wet processing) found in the industry. Wet production is dependent on the weight of material in the final product and it may be noted in the table that mills producing light weight products such as hosiery and other sheer knit goods occupy the smaller production ranges while mills manufacturing heavy weight woven goods (upholstery and drapery fabric) and carpet occupy the larger production ranges. Within individual manufacturing segments, variations in production are substantial as evidenced by the fact that all but two segments have production ranges of two to three orders of magnitude. The woven fabric finishing segment is clearly the largest, with more than twice as many facilities than any other segment processing greater than 25,000 kg/day (55,000 lb/day).

Wastewater discharge quantities, methods of discharge, and general treatment status are illustrated in Tables III-7 and III-8 and Figure III-1, respectively. Table III-7 illustrates the distribution of discharge volume for the mills in each segment of manufacturing. Each segment shows variation in discharge of from two to four orders of magnitude. The largest dischargers are in the Woven Fabric Finishing manufacturing segment, which has over five times as many mills as any other segment discharging greater than 5,000 cu m/day (1.3 mgd). The smallest discharges are associated with Hosiery Finishing, Nonwoven Manufacturing, and Felted Fabric Processing facilities with 87, 76, and 90 percent of the facilities, respectively, discharging less than 1,890 cu m/day (0.5 mgd).

Based on the results of the industry survey, it is estimated that over three-fourths of the wet processing facilities in the industry

TABLE III-5
GEOGRAPHICAL DISTRIBUTION - MILLS ON MASTER LIST

Manufacturing Segment	EPA Region I	II	III	IV	V	VI	VII	VIII	IX	X	All Regions
Wool Scouring	6	1	3	3	0	3	0	0	0	1	17
Wool Finishing	20	2	4	3	1	1	1	1	0	4	37
Low Water Use Processing	86	108	125	463	11	8	1	0	4	2	808
Woven Fabric Finishing	69	54	34	155	11	3	1	2	7	0	336
Knit Fabric Finishing	27	58	45	134	9	1	2	0	6	0	282
Hosiery Finishing	2	2	9	139	5	2	0	0	0	1	160
Carpet Finishing	0	1	4	39	1	4	0	0	9	0	58
Stock & Yarn Finishing	33	19	31	120	6	3	1	0	4	0	217
Nonwoven Manufacturing	10	3	4	11	7	2	0	0	1	0	38
Felted Fabric Processing	7	2	3	3	2	0	0	0	3	0	20
All Segments	260	250	262	1070	53	27	6	3	34	8	1973

TABLE III-6
PRODUCTION SIZE - MILLS ON MASTER LIST

Manufacturing Segment	Mills Within Given Production Range, kkg/day											
	0-2	2-4	4-9	9-13	13-22	22-34	34-45	45-68	68-91	91+	Un-known	All Mills
Wool Scouring	2	3	0	1	4	2	2	2	0	0	1	17
Wool Finishing	8	9	9	2	1	2	2	0	0	0	4	37
Low Water Use Processing	10	7	11	19	23	21	7	5	3	2	700	808
Woven Fabric Finishing	36	27	33	28	33	21	20	12	9	21	96	336
Knit Fabric Finishing	43	26	34	29	48	21	7	9	5	1	59	282
Hosiery Finishing	94	25	10	5	2	0	0	0	0	0	24	160
Carpet Finishing	2	2	7	3	8	5	6	7	5	5	8	58
Stock & Yarn Finishing	32	47	35	23	25	20	6	7	1	2	19	217
Nonwoven Manufacturing	3	3	2	4	3	5	2	2	0	1	13	38
Felted Fabric Processing	6	5	2	1	0	0	0	1	0	0	5	20
All Segments	236	154	143	115	147	97	52	45	23	32	929	1973

TABLE III-7
WASTEWATER DISCHARGE - MILLS ON MASTER LIST

Manufacturing Segment	Mills Within Given Discharge Range, 10^2 cu m/day (mgd) 0-0.36 (0.-0.009)	0.36-3.70 (0.010-0.099)	3.70-18.9 (0.10-0.49)	18.9-37.8 (0.50-0.99)	37.8-94.6 (1.0-2.4)	94.6-378 (2.5-10.0)	Un-known	All Mills
Wool Scouring	0	10	5	1	1	0	0	17
Wool Finishing	5	8	10	4	5	0	5	37
Low Water Use Processing	243	60	23	0	1	0	481	808
Woven Fabric Finishing	48	65	71	33	35	19	65	336
Knit Fabric Finishing	39	60	68	44	26	3	42	282
Hosiery Finishing	57	69	13	0	0	0	21	160
Carpet Finishing	2	7	17	16	9	0	7	58
Stock & Yarn Finishing	27	61	70	25	18	1	15	217
Nonwoven Manufacturing	16	7	6	2	0	0	7	38
Felted Fabric Processing	7	1	10	0	0	0	2	20
All Segments	444	348	293	125	95	23	645	1973

TABLE III-8

DISCHARGE TYPE - MILLS ON MASTER LIST

Manufacturing Segment	Total Mills Listed	Direct Discharge	Indirect Discharge	Discharge Unknown
Wool Scouring	17	7	10	0
Wool Finishing	37	10	24	3
Low Water Use Processing	808	24	87	697*
Woven Fabric Finishing	336	82	224	30
Knit Fabric Finishing	282	48	221	13
Hosiery Finishing	160	8	152	0
Carpet Finishing	58	13	42	3
Stock & Yarn Finishing	217	36	175	6
Nonwoven Manufacturing	38	12	25	1
Felted Fabric Processing	20	5	14	1
	1973	245	974	754

* 196 mills reported no discharge of process-related wastewater

discharge process-related wastewater to Publicly Owned Treatment Works (POTW). Table III-8 illustrates the numbers of mills on the master list that are direct dischargers, indirect dischargers, or for which the discharge could not be determined because of limited information. At one extreme, 95 percent of the hosiery mills discharge to POTW (indirect discharge), while on the other extreme, less than 60 percent of the wool scouring mills employ this method of discharge.

Figure III-1 illustrates the level of wastewater treatment provided by direct and indirect dischargers. Over half of the indirect dischargers provide no treatment of process-related wastewater, while slightly less than 10 percent provide treatement processes equivalent to, or better than, the recommended Best Practicable Technology (BPT). Over two-thirds of the direct dischargers provide treatment at the BPT level. Direct dischargers without treatment are predominantly mills waiting to tie into POTW presently in the design or construction phases.

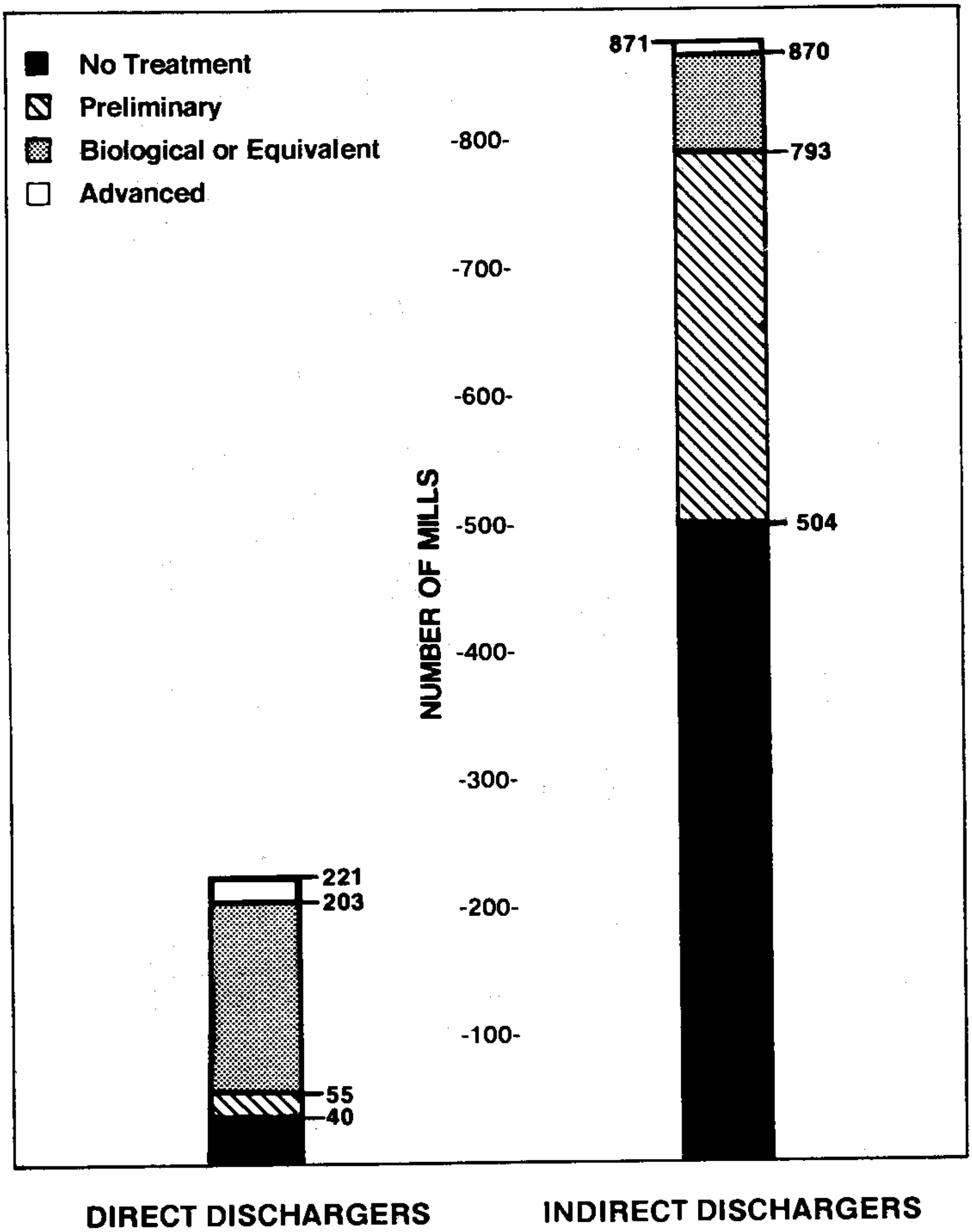
PROFILE OF MANUFACTURING

It has been noted that the textile industry (SIC Major Group 22) consists of approximately 6,000 manufacturing facilities. These facilities are engaged in various processing operations required to transform fiber -the industry's basic raw material -- into yarn, fabric, or other finished textile products. Approximately 70 percent of the facilities are believed to perform manufacturing operations that require no process water and an additional 10 percent are believed to 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 section discusses the principal raw materials utilized by the industry, final products manufactured by the industry, and the processing operations required. Emphasis is placed on operations and products requiring large quantities of process water.

Raw Materials

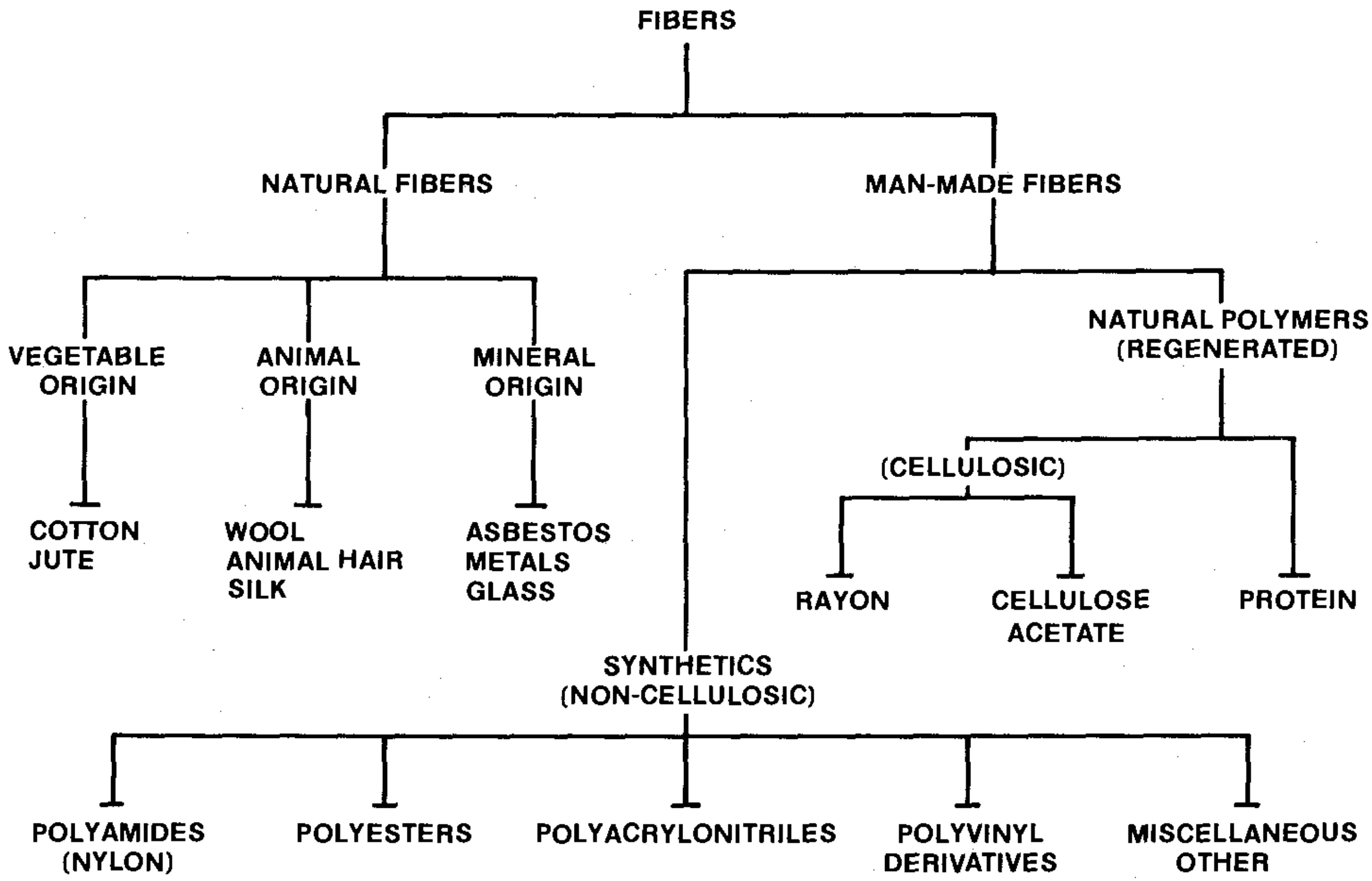
Various natural and man-made fibers are suitable for use in the manufacture of textiles (Figure III-2). Presently, wool, cotton, and man-made fibers (synthetics, rayon, and cellulose acetate) are the basic fibers used. The term "synthetic" is often used synonymously with the term "man-made" when referring to fiber, but as shown in Figure III-2, a more restricted definition may be more preferable. In this system, man-made fibers include synthetic fibers which are synthesized, usually from simple monomers, and natural polymer fibers which are manufactured from naturally occurring raw materials and thus are referred to as regenerated fibers. Synthetic fibers represent the

FIGURE III-1
WASTEWATER TREATMENT STATUS - WET PROCESSING MILLS ON MASTER LIST*



* Does not include 808 mills classified as "Low Water Use Processing," 57 mills that could not be contacted, and 16 wet processing mills for which the treatment could not be classified.

FIGURE III-2
FIBERS USED IN THE MANUFACTURE OF TEXTILES (9,10)



major portion of man-made fibers in use, and since the term "synthetic" is commonly used to refer to all man-made fibers, synthetic fibers will mean man-made fibers for the purposes of this document.

In 1977, wool consumption by the industry (computed on a scoured basis) was approximately 0.05 billion kilograms (0.12 billion pounds), cotton consumption 1.6 billion kilograms (3.6 billion pounds), and synthetic fiber consumption 4.0 billion kilograms (8.8 billion pounds) (11).

Other fibers such as animal hair, silk, and glass are also used, but consumption is insignificant in comparison to the above.

The natural fibers of most significance are supplied in staple (short fiber) form whereas the synthetic fibers are supplied as either staple or continuous filament. The steps required to prepare these fibers for processing are highly dependent on fiber type.

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 (10). Thorough scouring of this fiber prior to spinning and other processing is an absolute necessity, and there are a number of mills in the industry (Subcategory 1 - Wool Scouring) that perform this function only.

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.

Synthetics (Man-made). Synthetic fibers are classified as cellulosic and non-cellulosic based upon whether they are produced from cellulose or from synthesized organic materials (Figure III-2). Cellulosic fibers comprise the bulk of regenerated man-made fiber production. Total synthetic fiber consumption was two and a half times that of cotton in 1977. Major cellulosic fibers are rayon and cellulose acetate. Noncellulosic fibers, including nylon (polyamides), acrylics, modacrylics, and particularly polyester are more extensively used than cellulosic fibers. There are other fibers in both classes, but at present they are not consumed in as large a volume as those noted above. Synthetic fibers are much cleaner than cotton fibers, and thus do not require the extensive dry fiber preparation processes used with cotton.

Major Dry or Low Water Use Processes

Depending on the primary fiber type, a variety of production processes, some completely dry in terms of water requirements and some resulting in wastewater discharge, are used to manufacture the various products of this industry. In general, most of the dry- or low water use-processing operations precede the wet processing operations in the manufacturing sequence.

Spinning. Spinning is the process by which the 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) may also be performed during yarn manufacture.

In some instances yarn is dyed and finished, and production of yarn and thread for consumers may be an end in itself. Usually, however, manufactured yarn is used within the industry for tufting, knitting, weaving, or other fabric manufacturing.

Tufting. Mechanical tufting is currently 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.

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 are usually applied to the yarn to provide lubrication during stitching. These oils enter wastewater streams in subsequent wet processes.

Weaving. Weaving is the most common means 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. However, use of such looms is not widespread in this country at this time. In addition, an air-jet loom has recently been introduced which uses sequential pulses of air to propel the filling yarn. With the exception of water-jet looms, weaving is a completely dry operation. However, in order to prevent warp yarn breakage due to friction during the weaving operation, a step known as slashing is usually necessary and a small amount of wastewater may be generated at weaving (greige) mills as a result.

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 equivalent to as much as 15 percent of the weight of the fabric (12). The most common sizing agents are starch, polyvinyl alcohol (PVA), carboxymethyl cellulose (CMC), and polyacrylic acid (PAA). Starch is traditionally associated with the sizing of cotton. As previously mentioned, slashing may result in occasional wastewater discharges, usually due to spillage and the cleaning of slasher boxes, rolls, and size makeup kettles.

Other Fabric Manufacturing. Two other general fabric manufacturing methods, in addition to the more common and conventional methods previously described, are felted fabric manufacturing and nonwoven fabric manufacturing. These manufacturing methods do not involve yarns. Instead, they are built up from a web or continuous sheet of fibers. The differences between felts and nonwovens lie 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 role of synthetics (mostly rayon and polyester) has become more important in recent years. Felts are made by physically interlocking the fibers through a combination of mechanical working, chemical action, moisture, and heat.

Manufacturing of nonwoven textiles can be considered an industry in itself. Nonwovens, or webbed textiles, are used in numerous applications, and more and more uses are being discovered as the relatively new industry expands. Primarily, nonwoven textiles 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 is usually 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 whatever method, bonding is usually achieved by padding, dipping, or spraying with adhesives such as acrylic or polyvinyl acetate resins. A less common bonding method that is applicable to low melting point fibers only is to fuse the fibers together thermally.

Adhesive Processing. Adhesive-related 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 all generally dry or extremely low in water use, although waste 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-related processes follow.

Bonding is performed to join two textile materials together in a permanent union 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 can be extended. Fabric-to-fabric bonding is most commonly 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 then heat cured 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 are then joined as they pass through rollers. The second fabric is 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. Related to laminating is the specialized textile process of carpet backing, used to secure the yarns and to impart dimensional stability. It is achieved by bonding a foamed latex or jute backing to the carpet's underside. Latex adhesives typically are used in both cases. An alternative to latex adhesives is the application of a hot melt (thermoplastic) composition.

Fabric coating employs various chemicals and synthetic resins to form a relatively distinct, continuous film on a base fabric. Polyvinyl chloride 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 are generally coated by knife over roll coaters, and the melts are applied by calenders. Although coatings of PVC plastisols and melts are the most common, other substances and methods may also be employed for various reasons. One important process is the application of latex-based 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 vulcanization.

Flocking is the process by 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 can be achieved by spray or electrostatic techniques.

<u>Functional Finishing</u>. 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, waterrepellent, flame-resistant, mothproof, mildew-resistant, bacteriostatic, and stain resistant. Although the range of chemicals used is very broad, the wastewater generated during application is usually relatively small. The finishes are most often applied to the fabric from a water solution and several finishes may be applied from a single bath. Application is by means of rollers (calenders) that transport the finish(s) from a trough to the surface of the fabric. The finish(s) are then dried and cured (some permanently) onto the fabric. The only wastewater is from 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 permanancy. The silicone treatments can stand repeated washings or dry cleanings if properly applied. In addition to water, the silicones successfully repel oily fluids as well.

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

Mothproofing finishes typically are applied to wool and other animal hair fibers. Fabric made from these fibers are impregnated with chemicals that make them 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 toxic compounds that destroy their growth. Those commonly used contain chlorinated phenols or metallic salts or zinc, copper, or mercury. Hygienic additives also are employed to inhibit the growth of bacteria. They 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 make use of 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 can be performed before or after the chemical treatment but do not result in wastewater.

Major Wet Processes

Most high water use textile manufacturing processes occur during the conventional finishing of fiber and fabric products. The most significant 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 not unusual for desizing, scouring, and mercerizing operations to be placed in tandem with the continuous bleaching range to enable cotton to be finished more efficiently. It should be understood that a variety of wet finishing situations of this type may occur, depending upon factors such as processes employed, type and quality of materials and product, and original mill and equipment design.

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 may also be present. Practically all of the natural and acquired impurities in wool are removed in the scouring process.

Two methods of wool scouring, solvent and detergent scouring, are practiced. In the U.S., the latter is used almost exclusively. In the detergent process the wool is raked through a series of 1500- to 3000-gallon scouring bowls known as a "scouring train." Unless the first bowl is used as a steeping or de-suinting bowl, the first two bowls contain varying concentrations of either soap and alkali, or non-ionic detergents of the ethylene oxide condensate class. The soap-alkali scouring baths are generally characterized by a temperature of 32° to 40°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 43° to 57°C (135° to 160°F). The last two bowls of the scouring train are for rinsing and a counterflow arrangement is almost always 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 is often covered with a greasy scum. It has been estimated that for every pound of fibers obtained, one and one-half pounds of waste impurities are produced. Since the wool grease present in the scour liquor is not readily biodegradable and is of commercial value, grease recovery is usually practiced. In the most typical recovery process, the scour liquor is first piped to a separation tank where settling of grit and dirt occurs. The supernatant from the tank is then 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 is normally refined further to produce lanolin. Acid-cracking, utilizing sulfuric acid and heat, is an alternative method of grease recovery, but it is not widely practiced at this time.

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 upon 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 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 then used to remove the alkalinity. As a result, the overall water requirements for the carbonization of wool are substantial.

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 is used to provide the needed lubrication and moisture for proper felting action. The soap or detergent is usually mixed with sodium carbonate and a sequestering agent in a concentrated solution. In acid fulling, which may be used to prevent bleeding of color, an aqueous solution of sulfuric acid, hydrogen peroxide, and small amounts of metallic catalysts (chromium, copper, and 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 since all of the solution stays in the cloth. At this point, from 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 is usually 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 is usually soaped a second time in a stationary bath with a 2 percent solution of soap or synthetic detergent. This is followed by a second warm rinse at 40°C (105°F) and a cold rinse to cool off the cloth.

Desizing. Desizing removes the sizing compounds applied to the yarns 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 utilizes a solution of dilute sulfuric acid to hydrolyze the starch and render it water soluble. Enzyme desizing utilizes vegetable or animal enzymes to decompose starches to a water soluble form. In either case, the desizing agent is normally 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 merely washed with water.

Scouring. Scouring is employed to remove natural and acquired impurities from fibers and fabric. The nature of the scouring operation is highly dependent upon fiber type; raw wool scouring has been discussed separately due to its uniqueness among textile processes. The comparative lack of impurities associated with synthetic fabrics allows much milder scouring than that required for cotton goods.

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. An additional function of cotton scouring is to make the fibers whiter and more absorbent for subsequent bleaching and dyeing. Scouring of cotton is often done in conjunction with desizing rather than as a totally separate operation and is usually 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 90°C (220°F), pH values of 10 to 13, and pressures of 10 to 20 psig for 6 to 12 hours. The fabric is then cooled and rinsed in the kier. Goods processed in the open width are normally scoured in open-width boil-out machines, also known as progressive jigs. The goods are continuously fed 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 completely rinsed to clean the fibers and remove residual alkali.

The manufacture of synthetic fibers is well controlled so they are relatively free of impurities. Consequently, only light scouring and little or no bleaching is required prior to dyeing. However, sizes applied to synthetics are often removed in the scouring process rather than in a separate desizing step. Scour baths usually contain weak alkalis, anti-static agents, lubricants, and soap or detergents. 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 employed. After scouring, the goods are rinsed to remove excess material in preparation for the dye bath.

Either light or heavy scouring of wool goods may be performed during wool finishing to remove acquired impurities.

<u>Mercerizing</u>. 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 is usually 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 alkali is absorbed, with higher concentrations, longer residence times, and lower temperatures favoring 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 thoroughly washed off, sometimes with the aid of an intermediate acid wash. In many mills, the sodium hydroxide is reclaimed in caustic recovery units and concentrated for re-use in scouring or mercerization. It is presently 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.

<u>Bleaching</u>. 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 and waxes, and small particles of foreign matter. It is usually performed immediately after scouring or mercerizing and prior to dyeing or printing; bins, jigs, or continuous equipment may be employed. Bleaching is primarily accomplished 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, is first 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 65° to 68°C (175° to 180°F) for approximately 40 to 60 minutes, resulting in the conversion of fats and waxes to soaps. The material is then 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 a temperature of 76°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 employed 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 is then passed through a solution of sodium hypochlorite and allowed to bleach out in bins (batch) or J-boxes (continuous) for the necessary period of time. A final rinse is then performed.

Bleaching methods for synthetic fabrics are dependent upon fiber type. Since 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. Non-cellulosic fibers (polyesters, acrylics, nylons) are not usually bleached unless blended with natural fibers. 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 is usually 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.

<u>Dyeing</u>. 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.

In short, 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 factors that cause a substance to absorb and reflect light waves are complex and beyond the scope of this section. Presented here are the methods of dyeing, the types of dyestuffs and auxiliary chemicals used in dyeing, and the types of equipment available and in use for application of dyes.

The mechanisms of dyeing textile fibers can be summarized as follows (10):

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 forces of a physical nature.

Dye/fiber interfacing is a function of the type of equipment utilized, while the specific dye formulas provide the chemical environment for bonding to take place. Dyeing can be performed while the goods 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 environmental 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 18 inches 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 that are to be used for worsted fabric are typically 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 are circulated, providing optimum environmental 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 environmental conditions, and rinsing. Warp yarns wound on large perforated beams are also dyed using the package method. The beams of dyed yarn can be used directly in weaving.

Package dyeing has become favored over skein dyeing because skein-reeling is a comparatively expensive process, more working space is required, and the skein-dyed yarn must always 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 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 is finally rinsed. Two or more dyes can be padded. The process has become especially important to the manufacture of tufted carpet.

Fabric dyeing is the most common 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 commit itself to large yardages. 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 in use. 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 environmental conditions and residence time must be provided as in the other previously described methods.

Jet dyeing is also 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, reducing the risk of tangling, providing a more uniform temperature, reducing elongation of the fabric due to 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. Since only a few meters of the fabric are immersed at a time, it is possible to work with an exceedingly short liquor ratio. Jig dyeing is particularly attractive for cellulosic fibers because the dyes used generally do not exhaust well, and less dyestuff is wasted.

Continuous dyeing is also 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 that dry the fabric.

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 is then heated to 180° to 220°C (380° to 454°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 for the purposes of this document and is discussed below. Classification according to chemical constitution is not discussed, but the reader is referred to the Colour Index, Volume III, published by the Society of Dyers and Colourists and the American Association of Textile Chemists and Colorists for a thorough coverage of this subject.

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

Dye Class	Applicable Fiber Types
Acid	Protein, polyamide (nylon)
Azoic (Naphthal)	Cellulosic
Basic (Cationic)	Acrylic, silk, wool, cellulosic if mordanted
Direct	Cellulosic
Disperse	Cellulosic, acetate, synthetics (man-made)
Mordant (Chrome)	Protein, cellulosic
Reactive	Cellulosic, wool, silk
Sulfur	Cellulosic
Vat	Cellulosic, wool, silk

Acid Dyes. These dyes are sodium salts, usually of sulphonic acids, but in a few cases carboxylic acids. They are invariably manufactured as sodium salts because the free dye acids are more difficult to isolate and they are hygroscopic, which makes them difficult to pack and store. They have a direct affinity toward protein fibers and are the main class of dyes used in wool dyeing. Most will not exhaust on cellulosic fiber but, since they 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 environmental conditions suitable to the type of dye being 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. Since naphthol is used as the coupling component, they are referred to as naphthol dyes by the industry. They are used for dyeing cellulosic fibers when comparatively good wet-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 Colour Index, 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 necessary 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 are often referred to as cationic dyes. Because of poor fastness to light, these dyes had virtually been discontinued until it was discovered that they would dye acrylic fibers and give bright, clear shades of good light-fastness. Cellulosic fibers have, for all practical purposes, no affinity for basic dyes. The dyes can be applied to cellulose if the fibers are mordanted before dyeing; however, these dyes are very rarely, if ever, applied to cotton these days. 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 dyes, 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 are frequently 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, and their wash- and lightfastness 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 employed, 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. Hydrophobic fibers, such as secondary or tertiary cellulose acetate, and the synthetic fibers will often dye better with insoluble dyes than those that are dissolved in water. These dyes are suspensions of finely-divided organic compounds with very slight aqueous solubility.

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. They have no natural affinity for textile fibers, but are applied to cellulosic or protein fibers that have been mordanted with a metallic oxide. Since chromium is the most commonly used mordant, these dyes are often 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 very good wash-fastness.

The mordant dyes are most commonly applied in a boiling acid dyebath 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

Reactive Dyes. These are the latest dyestuff discovery and, because they react chemically with cotton, viscose, linen, wool, and silk, they possess very good wash-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
tri-sodium phosphate
tetra-sodium pyrophosphate

Sulfur Dyes. These dyes are complex organic compounds that contain sulfur linkages within their molecules. They are usually 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 are then oxidized in the fiber to the original and soluble sulfur dyes. These dyes have excellent resistance to washing, but poor resistance to sunlight. They will dye cotton, linen, and rayon, but the colors are not very bright.

In their reduced state, the dyeing properties of the sulfur dyes resemble those of the direct dyes. They exhaust better in the presence of electrolytes and vary considerably with regard to the temperatures at which maximum exhaustion takes place. They 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. There are the best known dyes in use today because of their all-around fastness to both washing and sunlight. They are among the oldest natural coloring matters used for textiles. They are insoluble in water and cannot be used without modification. When treated with reducing agents, they are converted into leuco (combining) compounds, all of which are soluble in water in the presence of alkali. The leuco compounds have an affinity towards cellulose and reoxidize to the insoluble colored pigment within the fiber when exposed to air. Vat dyes are made from indigo, anthraquinone, and carbazol and are successfully used on cotton, linen, rayon, wool, silk, and sometimes nylon. These dyes are also 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 hydrosulfite
dispersing agents
hydrogen peroxide
acetic acid
sodium perborate
sodium chloride

Printing. Printing of textiles is not unlike the process of dyeing. 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 is often referred to as localized dyeing. The color application techniques are, however, quite different.

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

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

The design can be transferred to the rollers by hand engraving, photo engraving, or chemical etching. The latter two methods are most used 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 are generally 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 wastewater associated with the printing process itself.

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

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 of today, 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, and given other finishing treatments for fineness and texture.

The semi-automatic process is quite similar to the manual process except that the fabric travels and the screens representing the pattern are kept in place. The handling of the screens and the application of the color are still 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 is automatically 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.

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 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). 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 result in wastewater discharge.

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 are also 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, thickener, and water.

Final Products

It has been noted earlier in this section that the Textile Mill Products group (SIC Major Group 22) includes 30 separate industries that manufacture approximately 90 classes of products. Throughout the 90 classes, there are hundreds of individual products and the number is constantly changing due to research, development, and marketing. Many of the industries and product classes do not require wet operations in their manufacture and, consequently, are not of specific interest here. To represent the wet-processing segment of the industry with regard to effluent limitations guidelines and standards of performance for wastewater discharge, 9 major subcategories have been established. The subcategories represent 13 processing classes at which the products are composed of characteristic raw material and at which the production is the result of similar manufacturing operations. It is not suggested that each processing class represents facilities that are completely homogeneous because that is definitely not the case. The textile industry, especially the wet processing segment, is highly variable and homogeneity is not found even among mills that have similar processes or products. A description of each major processing class follows.

Wool Stock and Top. Unlike cotton and synthetic fibers, raw wool is very dirty and must be extensively 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 in the industry. A schematic of a typical wool scouring operation is presented in Figure III-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 thoroughly dried to prevent racidity. The dried wool may be shipped as such, combed to create wool top, or finished in another portion of the mill.

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 Figure III-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,

FIGURE III-3
SUBCATEGORY 1: TYPICAL WOOL SCOURING PROCESS FLOW DIAGRAM

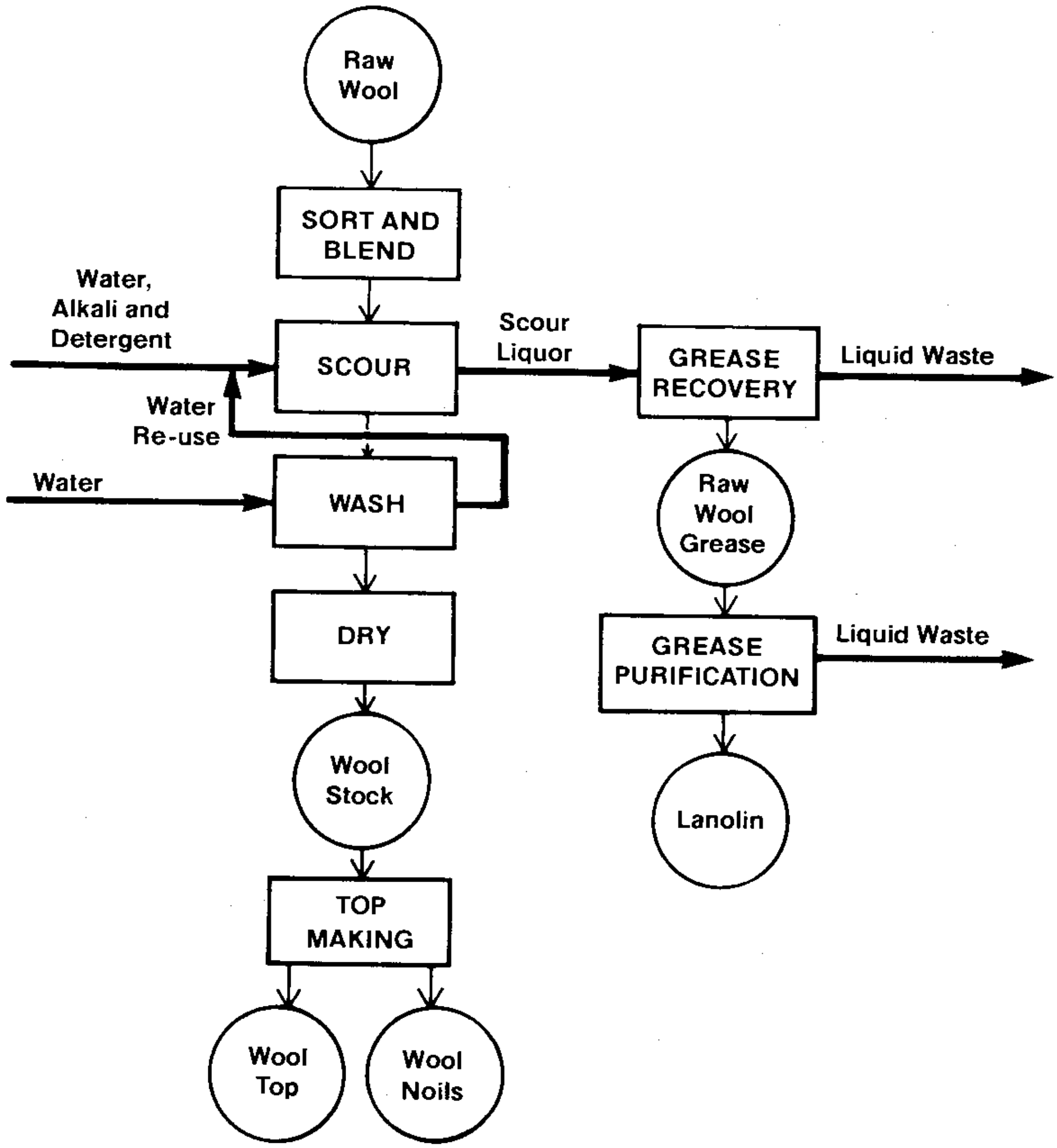
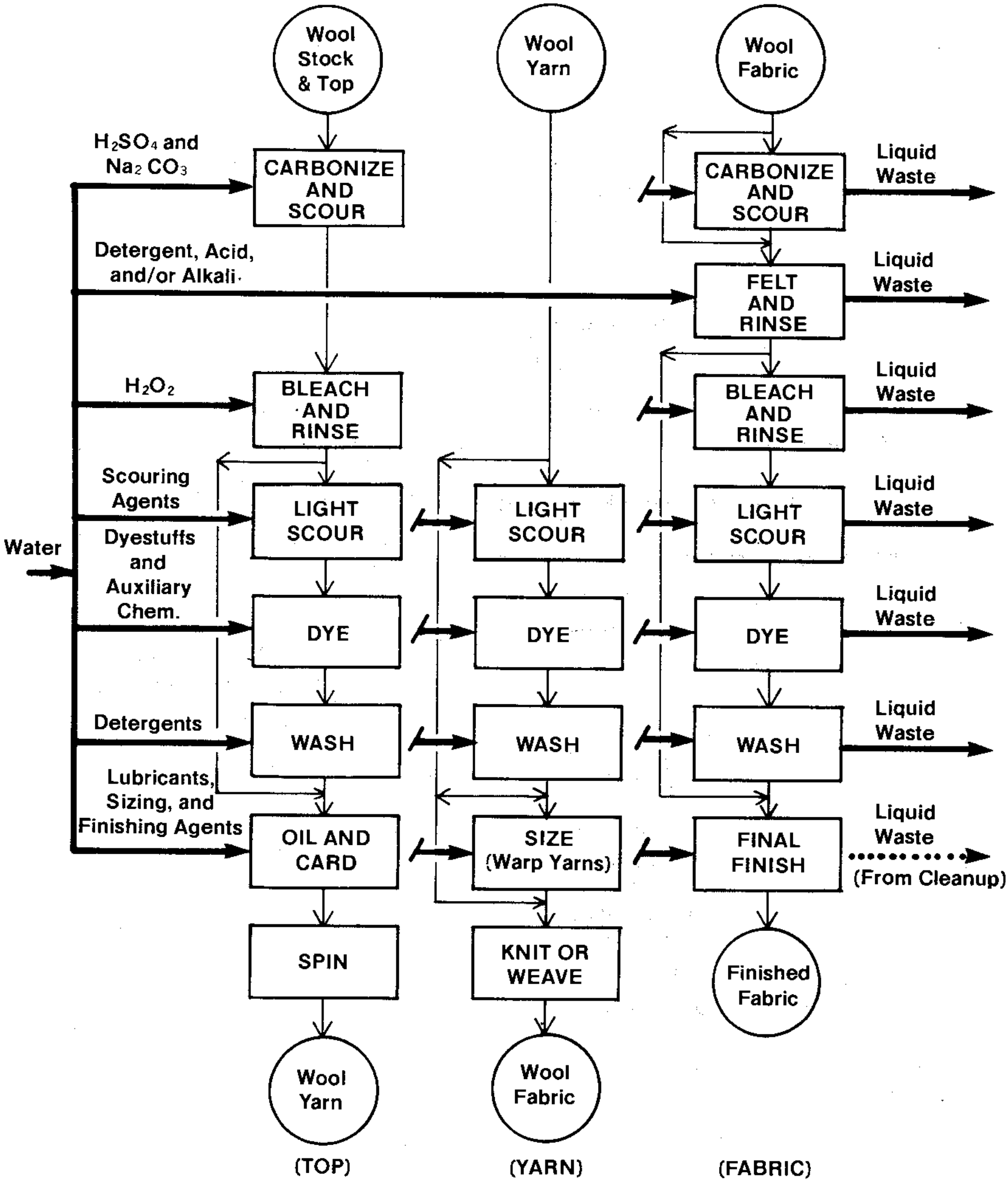


FIGURE III-4

SUBCATEGORY 2: TYPICAL WOOL FINISHING PROCESS FLOW DIAGRAM



and spinning may be performed when finishing wool top. Carbonizing and bleaching are also performed at mills finishing wool fabric, as is fulling (felting) and final finishing. Knitting or slashing and weaving must be performed to create wool fabric from yarn. This 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.

Greige Goods and Adhesive Related Products. Greige goods are materials that have been woven or knit, but not dry- or wet-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 process wastewater. A typical woven greige mill operation (Figure III-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.

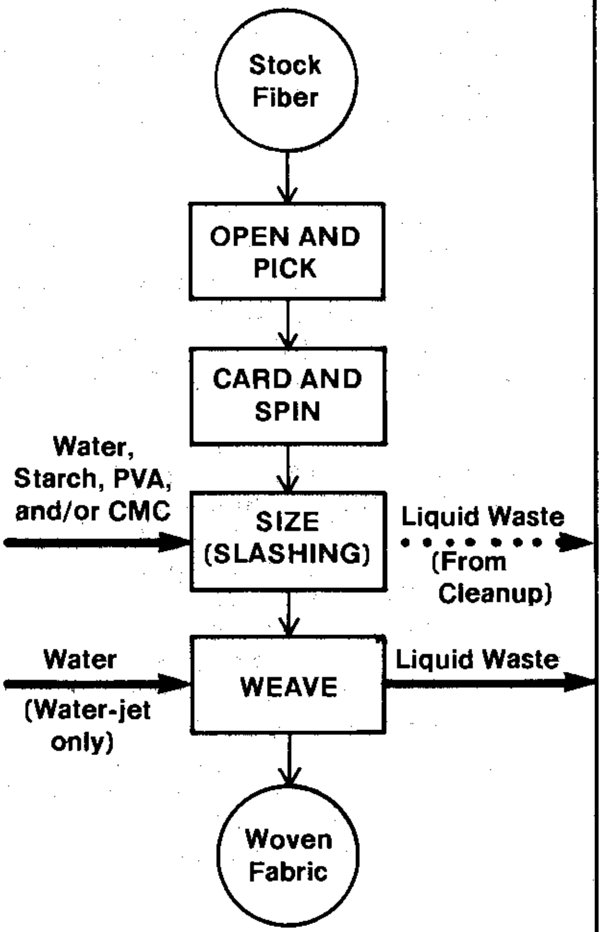
Adhesive related products are goods that have been created or modified due to operations such as bonding, laminating, coating, or flocking. Backed carpet, tire cord fabric, other coated fabrics, laminated fabric, and flocked fabrics are the principal products. A schematic of a typical adhesive-related operation is presented in Figure III-5. Application of adhesive, followed by setting or drying are the main adhesive related processes.

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 the mills in this subcategory. A typical process flow diagram is presented in Figure III-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.

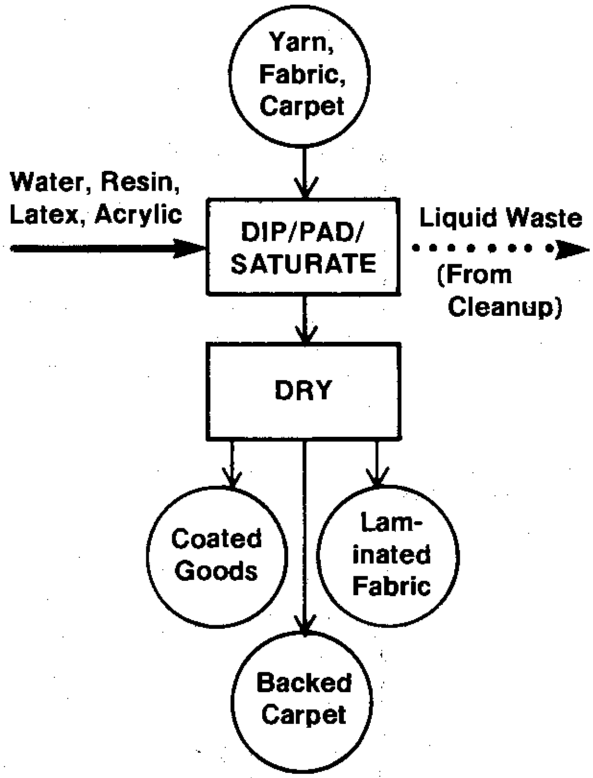
Finished Knit Goods. Finished knit goods include fabrics and hosiery. Principal fabric products are underwear, numerous types of outerwear, various types of household and industrial items, circular knits, and warpknits. Hosiery products include both conventional footwear and ladies nylon hose and pantyhose. Typical process flow diagrams for

FIGURE III-5

SUBCATEGORY 3: TYPICAL LOW WATER USE PROCESSING PROCESS FLOW DIAGRAMS



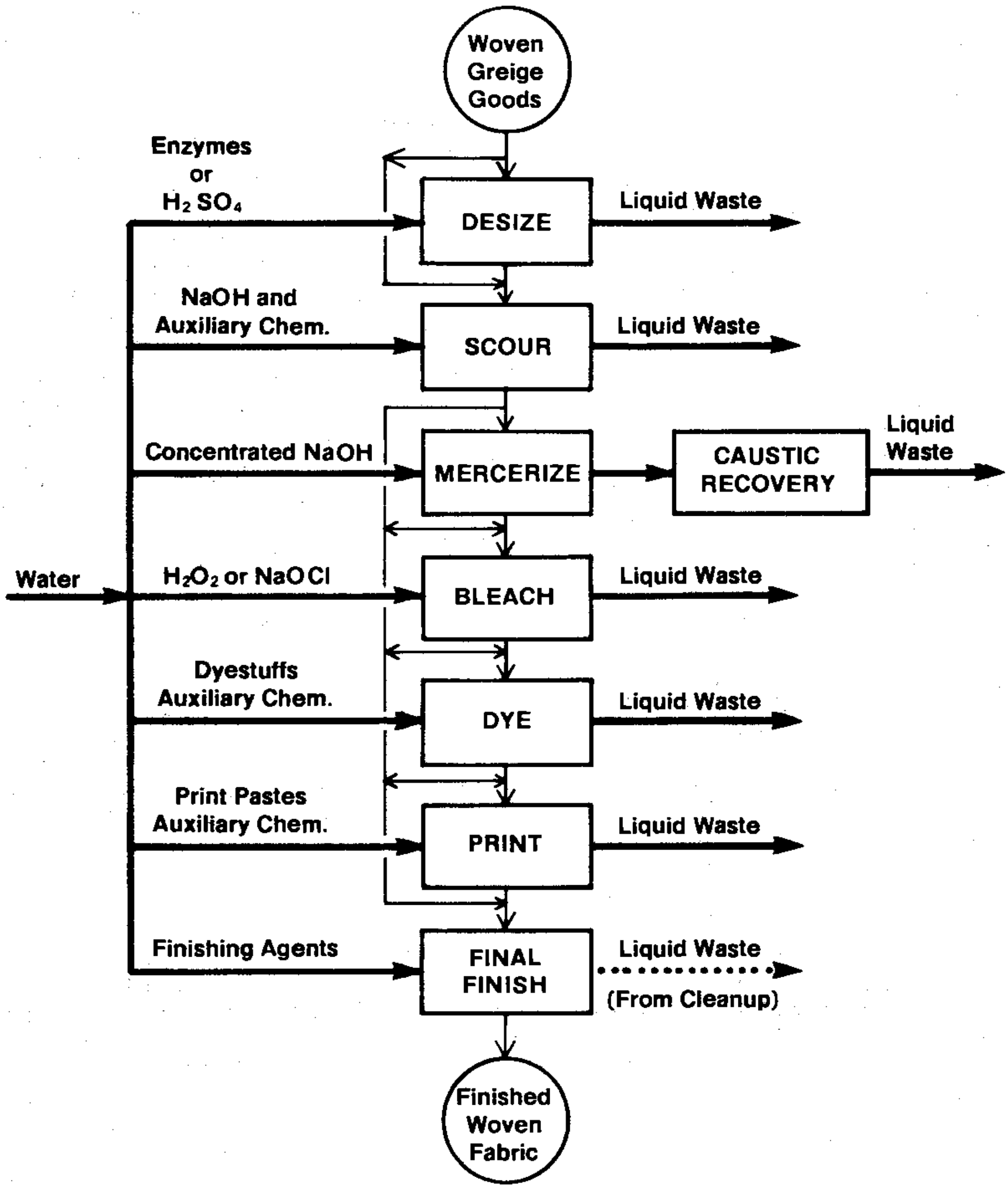
(WOVEN GREIGE GOODS)



(ADHESIVE RELATED)

FIGURE III-6

SUBCATEGORY 4: TYPICAL WOVEN FABRIC FINISHING PROCESS FLOW DIAGRAM



knit fabric processing and hosiery processing are presented in Figure III-7. Knit fabric finishing is similar to the finishing required for woven goods, except that desizing and mercerizing are not necessary. Hosiery finishing is generally much simpler, especially dyeing.

Finished Carpet. Carpet manufacturing is an important and distinct segment of the textile industry. Most carpet mills are integrated operations; tufting, finishing and backing carpet at the same location. Finishing operations that may be performed include scouring, bleaching, dyeing, printing, and application of functional finishing agents. A typical process flow diagram is presented in Figure III-8.

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

Nonwovens. 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 Figure III-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 is often discharged.

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 Figure III-11. Rinsing following fulling and dyeing (if employed) is responsible for the rather high water use of this segment.

Summary

Three primary fiber types are used to manufacture the principal products produced by the textile industry. While there is a large number of textile processing operations, the need for specific major operations is a function of the fiber type and the final product, each fiber/product combination having its own particular processing requirements. The principal products of the industry can be divided into 13 processing classes based on the similarity in the processing required. This subdivision is developed in the next section.

FIGURE III-7
SUBCATEGORY 5: TYPICAL KNIT FABRIC FINISHING PROCESS FLOW DIAGRAM

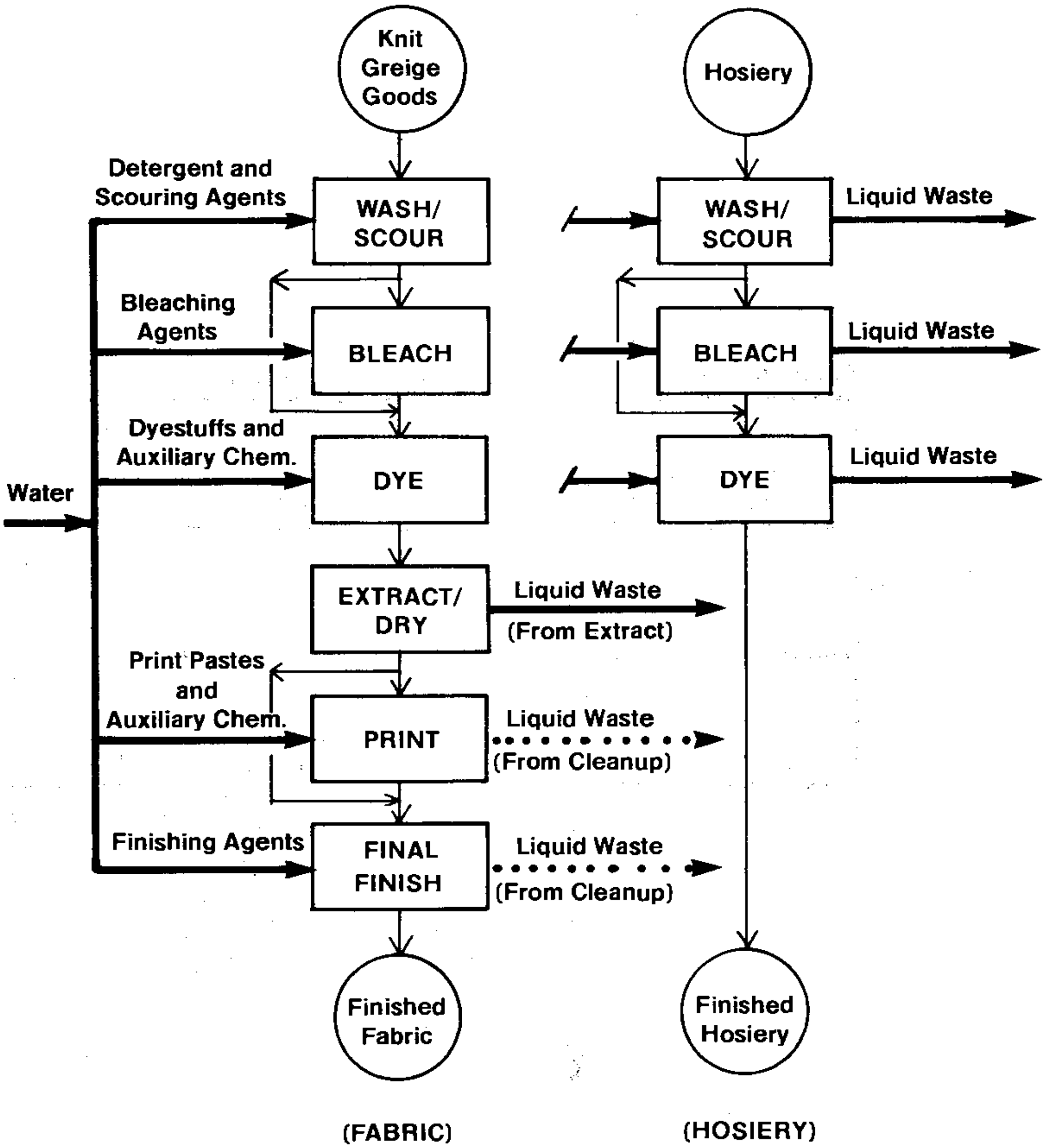


FIGURE III-8

SUBCATEGORY 6: TYPICAL CARPET FINISHING PROCESS FLOW DIAGRAM

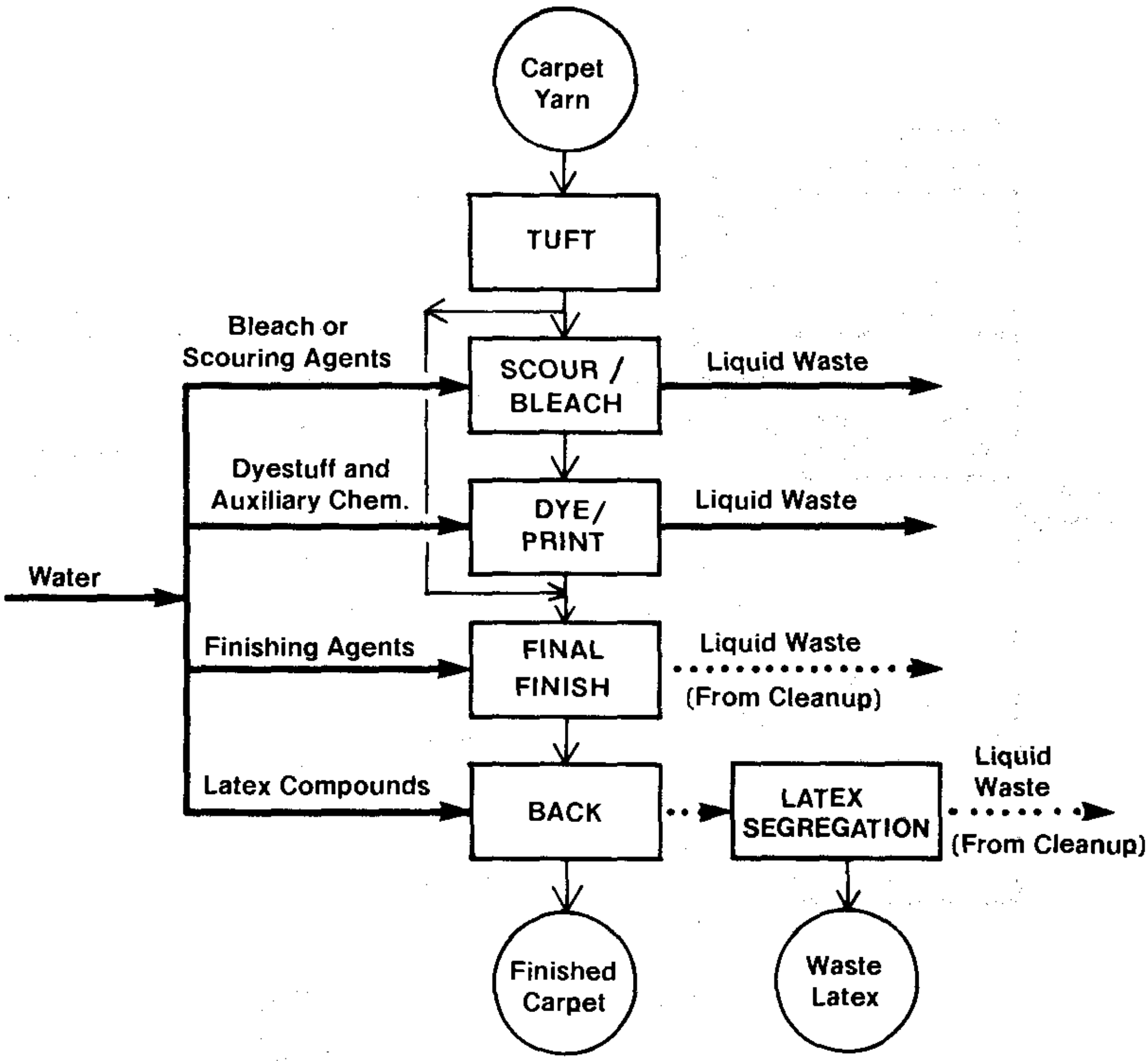


FIGURE III-9

SUBCATEGORY 7: TYPICAL STOCK AND YARN FINISHING PROCESS FLOW DIAGRAM

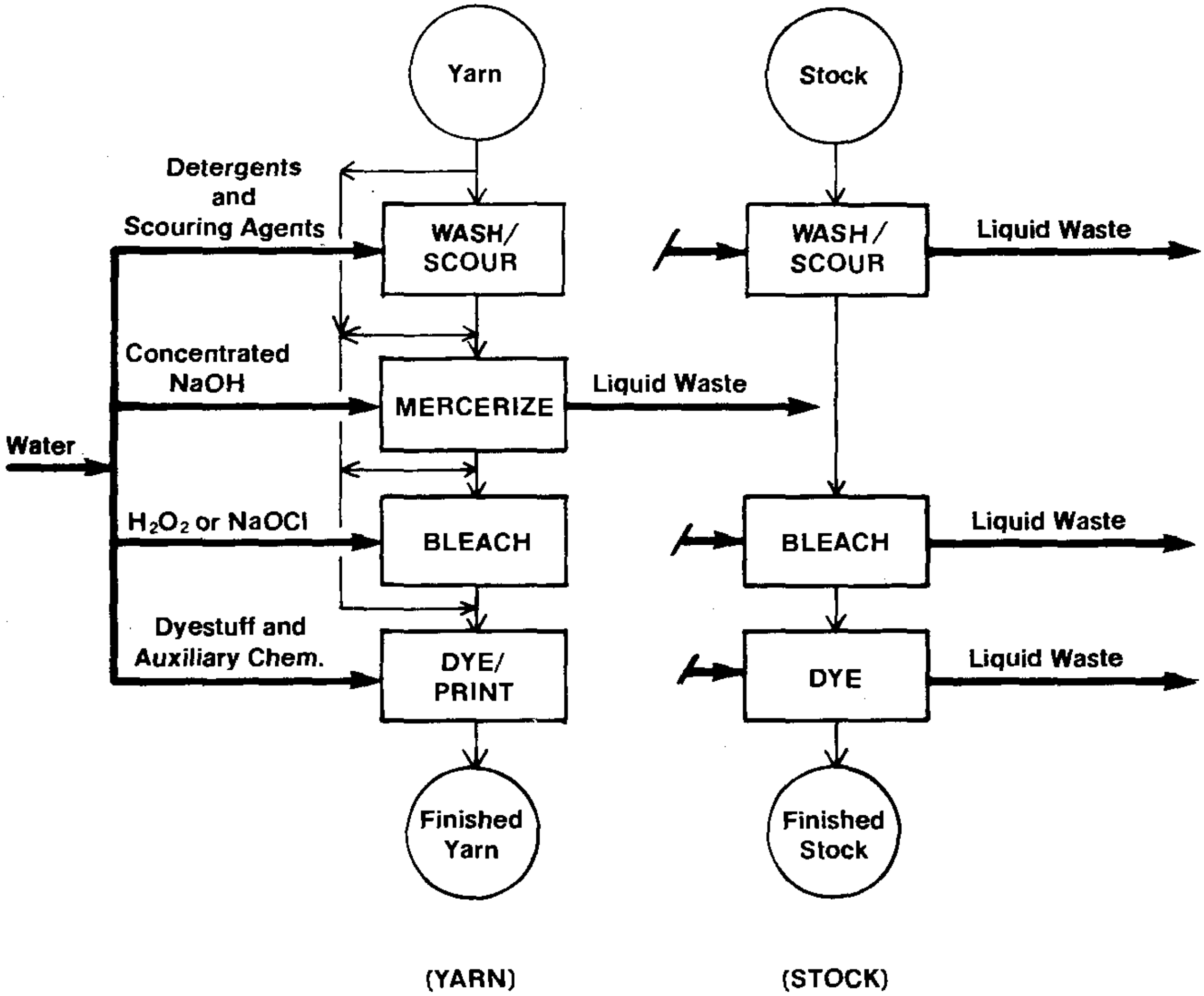


FIGURE III-10

SUBCATEGORY 8: TYPICAL NONWOVEN MANUFACTURING PROCESS FLOW DIAGRAM

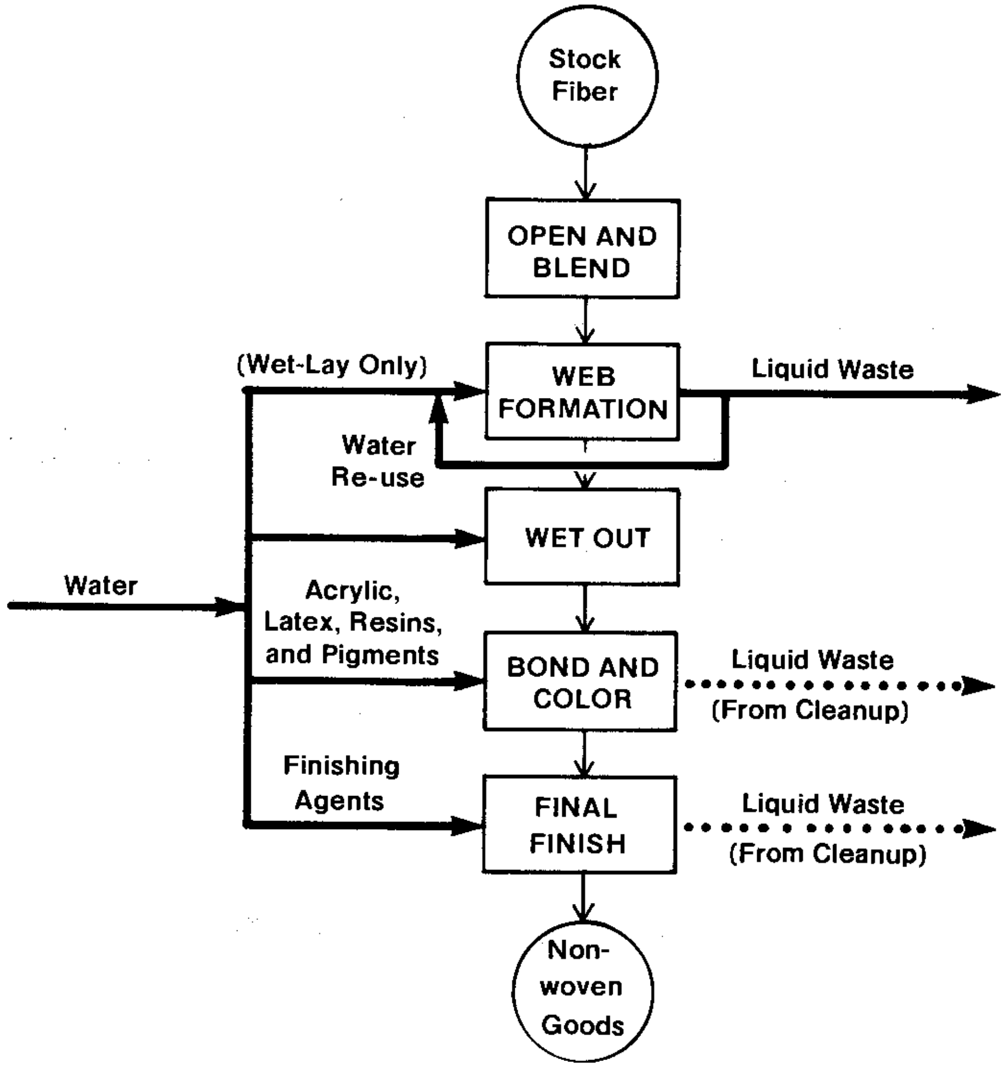
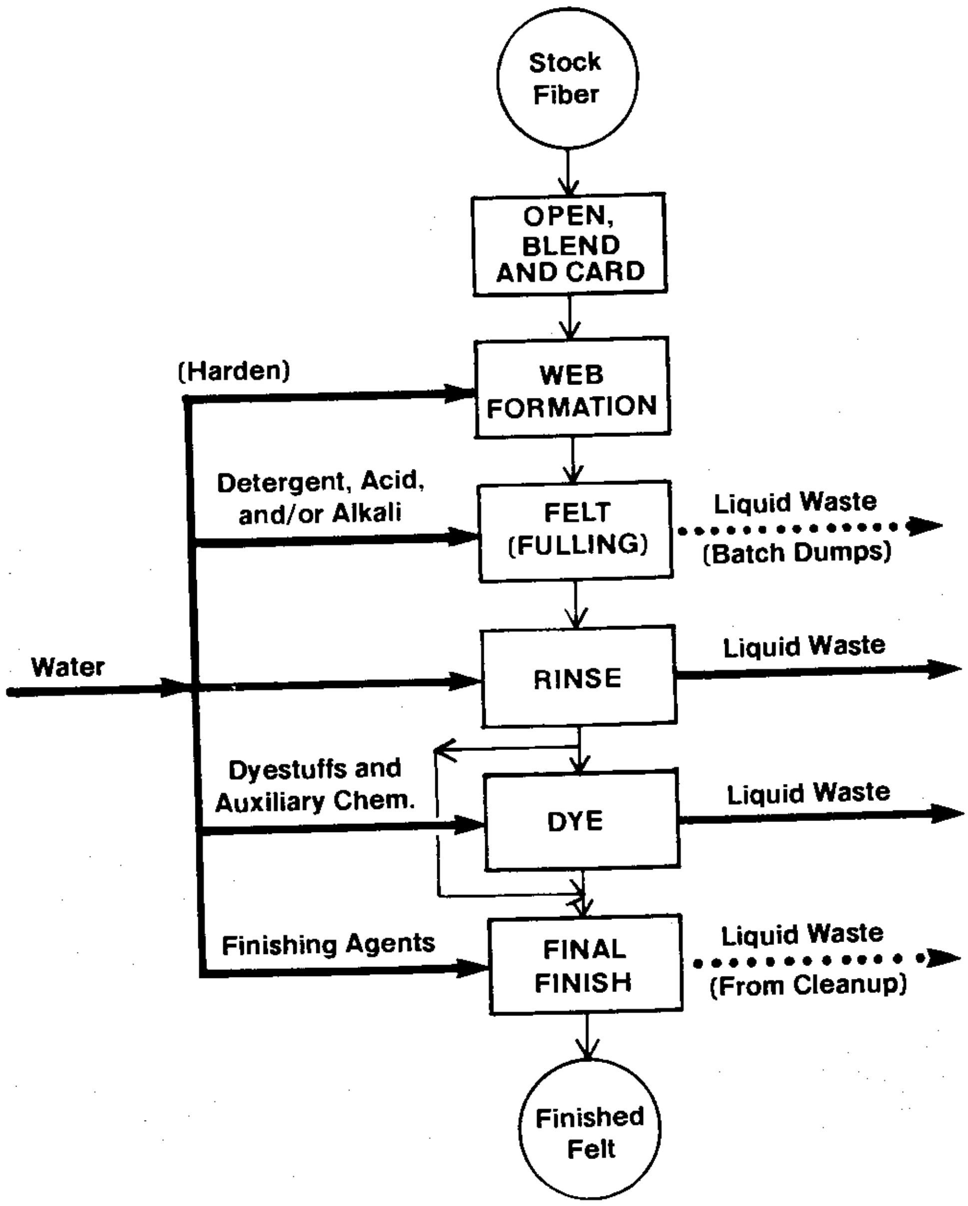


FIGURE III-11

SUBCATEGORY 9 - TYPICAL FELTED FABRIC PROCESSING PROCESS FLOW DIAGRAM



SECTION IV

INDUSTRY SUBCATEGORIZATION

SELECTED SUBCATEGORIES

Based on the findings detailed in this section, and supported by the discussions in Section V, the subcategories of the textile industry established for developing effluent limitations guidelines and standards of performance are as follows:

1. Wool Scouring
2. Wool Finishing
3. Low Water Use Processing
4. Woven Fabric Finishing
   a. Simple Processing
   b. Complex Processing
   c. Complex Processing Plus Desizing
5. Knit Fabric Finishing
   a. Simple Processing
   b. Complex Processing
   c. Hosiery Products
6. Carpet Finishing
7. Stock and Yarn Finishing
8. Nonwoven Manufacturing
9. Felted Fabric Processing

Raw materials, final products, manufacturing processes, and waste characteristics are all interrelated and constitute the most significant factors in the categorization of the industry. Raw materials and final products form the framework for the selected subcategorization, but some of the remaining factors are also important and are reflected in the subcategories and subdivisions developed.

PURPOSE AND BASIS OF SELECTION

Point source categories are subdivided to implement effectively the requirements of the Federal Water Pollution Control Act Amendments of 1972. The primary purpose of subcategorization is to divide the industry into segments that have similar discharge characteristics while maintaining a logical and manageable system.

The textile industry, because of its structure and the possible variations and combinations of end products, fiber compositions, and manufacturing and finishing processes, requires considerable study to develop well-defined groupings with similar waste characteristics. Factors to be considered in development and review of subcategories include raw materials used, products, manufacturing processes employed, size and age of mill and equipment, waste characteristics, water pollution control technology, treatment costs, energy requirements, and solid waste generation and disposal requirements. Various approaches aimed at classifying the industry have been used in the past, but each has certain drawbacks regarding subcategorization.

The Standard Industrial Classification (SIC) (13) system is the most widely used method of industrial classification. It is a highly structured system that is maintained by periodic survey. The system is oriented toward the collection and presentation of economic data related to gross production, sales, and unit costs. It is not directly related to actual plant operations, production processes, or considerations associated with water pollution control. Therefore, it does not lend itself well to categorization of the textile industry with respect to manufacturing processes and waste characteristics.

The report entitled "A Simplification of Textile Waste Survey and Treatment" (14) advanced the approach of synthesizing raw waste by additive contributions of the chemicals used. A similar scheme outlined in a report prepared for EPA (15) utilizes unit processes to synthesize raw waste loads. Both approaches are considered impractical to implement because of the nature of the drainage piping systems at most mills that prevents ready isolation of the wastewaters from individual steps in the manufacturing process.

Textile raw materials, further identified by product lines and associated effluents, have been the basis of categorization for most recent studies dealing with textile wastewater characteristics and treatment. Reports by EPA (1) and various researchers and consultants (4, 16) have categorized first on the basis of a very important raw material distinction, the processing of wool vs other textile fibers (primarily cotton and synthetics). Following this major division, both wool and other textile fibers have been further categorized based on products that in turn relate to types of wastes. Specific subcategories vary from scheme to scheme, although not radically, depending upon the extent of the information available. This study, as noted previously, is the most extensive to date and after comprehensive examination of the factors noted above has also found categorization on a raw material/product line/waste characteristic basis to be most appropriate. The study methods employed and justification for the recommended categorization are presented below along with discussions of other factors that were considered, but rejected as a basis for subdividing the industry.

<u>Statistical Analysis of Industry Segments</u>

Statistical methods were employed as an aid in subcategorizing the textile industry on the basis of waste characteristics. The Wilcoxon Two-Sample Test (17, 18, 19) (also known as the Mann-Whitney U Test) was used to substantiate eight major wet processing subcategories and to investigate the need for additional subcategories and internal subdivisions within the existing subcategories. Water usage rate (liters/kg of product) and BOD, COD, and TSS mass loadings (kg/kkg of product) were the parameters compared in the statistical testing.

The Wilcoxon Two-Sample Test was chosen as the test statistic because it is distribution free (nonparametric) and adaptable to large as well as small populations (less than eight values). The method tests the null hypothesis that two samples come from identical continuous populations against the alternative that the populations have unequal means. It is an alternative to the standard two-sample "t" test and is especially adaptable when the data being tested are non-normal in distribution (18). The test employs ranking of observations as the basis for statistical decision making and takes into account the relative position of each data value within the groups being tested. As the sample size increases the test statistics can be approximated closely by a normal distribution.

The major subcategories and product lines tested were essentially those established in earlier effluent guidelines studies of the textile industry and included wool scouring, wool finishing, woven fabric finishing, knit fabric finishing, carpet finishing, and stock & yarn finishing, plus hosiery products and nonwoven manufacturing. External comparisons (subcategory vs subcategory) were investigated for the knit fabric, hosiery, carpet, and stock & yarn product lines. Internal subcategorization was investigated in the woven fabric finishing, knit fabric finishing, carpet finishing, stock & yarn finishing, and nonwoven manufacturing subcategories, as well as hosiery products. The wool scouring and wool finishing subcategories could not be investigated for internal subcategorization because of the relatively small numbers of mills with useful wastewater characterization data.

Approximately 50 combinations of manufacturing process, type of discharge, production quantity, geographic location, mill age, and amount of automation were investigated as bases for internal subcategorizations. A need for internal subcategorization was determined to be necessary for the woven fabric and knit fabric finishing subcategories, and felted fabric processing was segregated from nonwoven manufacturing. Subdivisions in the other subcategories were not justified.

Raw Materials

The principal raw materials used by the textile industry are wool, cotton, and synthetic fibers. There are major differences in terms of processing, products, and wastewater characteristics that distinguish woolen mills from other textile operations and require an initial division on this basis.

Wool and other animal hair fibers, unlike cotton and synthetic fibers, require extensive cleaning and preparation prior to use in fabric, and these steps result in a characteristic wastewater. Even in the processing and finishing stages, wool, other animal hair fibers, and wool blends are subjected to many chemicals and processes that are unique to these materials. There are also differences in the processing of cotton goods and goods made from synthetic fibers. However, variations in wastewater characteristics between mills that process mostly cotton and those that handle primarily synthetics are not consistent, except for suspended solids. This pollutant is readily amenable to treatment, and subcategorization based on this difference was judged to be unwarranted. Another difficulty in subcategorizing on the basis of cotton vs synthetics is that many mills process substantial amounts of products containing both fibers. The relative consumption of each may vary substantially over short periods of time due to the demands of the market.

Final Products

Final products from textile mills cover a wide spectrum and, following the initial separation of wool from the other fibers, provide a rational basis for subcategorizing the industry. The industry can be divided into a number of general product lines. The processing of each line has associated chemical and water requirements, and generates characteristic wastewaters. The product lines specifically identified, excluding those requiring little or no wet processing, include scoured wool, finished wool goods, and the following finished cotton and synthetic products: woven fabric, knit fabric, carpets, stock and yarn, nonwovens, and felt goods. Mills that combine finishing and greige operations and those that produce woven, knit, and/or yarn products are categorized based upon the major finishing effort. Thus, although processing may sometimes involve activity in more than one product area, a particular product line almost always predominates and permits placement of each mill in the most appropriate subcategory. Wastewater characteristics associated with each subcategory are presented and discussed in Section V.

The distinct nature of the wastewaters generated by the subcategories can be observed in Table IV-1 where selected product lines are compared for the test statistics discussed previously. The differences in water usage rate are highly significant for each comparison except that between knit fabric and stock & yarn for which the COD and TSS statistics are significant.

TABLE IV-1
STATISTICAL SIGNIFICANCE - COMPARISON OF SELECTED PRODUCT LINES
EXTERNAL COMPARISONS

Product Lines Compared	Test Statistic*			
	Water Usage	BOD5	COD	TSS
Knit Fabric *vs* Hosiery	0.1	NS	NS	NS
Knit Fabric *vs* Carpet	0.1	NS	5	5
Knit Fabric *vs* Stock & Yarn	NS	NS	10	5
Hosiery *vs* Carpet	0.5	NS	5	NS
Hosiery *vs* Stock & Yarn	2	NS	NS	NS
Carpet *vs* Stock & Yarn	0.1	NS	NS	NS

* Values indicate level of significance in percent; NS indicates "Not Significant at 10% level." The level of significance represents the probability that an error has been committed in stating that two samples compared come from different populations.

Manufacturing Processes

Subcategories based on final product generally reflect differences between various manufacturing processes. The product subcategories selected were further segmented where necessary to allow for dissimilar levels of processing. Statistical methods were used to evaluate the advantage of further subdivisions within the various subcategories. It was established that complexity of manufacturing was most meaningful as a basis for categorizing groups of mills with wide differences in water usage rate and BOD, COD, and TSS mass loadings. Complexity of manufacturing here refers to the numbers and types of processes employed at a facility. A mill is considered to be a complex processing facility if more than one of the following processes - bleaching, dyeing, or printing - is applied to more than five percent of total production. Mills employing one of the processes only, or additional processes at less than five percent, are considered simple manufacturing facilities.

The results of statistical comparison within a number of subcategories, based on complexity of manufacturing, are presented in Table IV-2. As a result of the comparisons, further segmentation of the Woven Fabric Finishing and Knit Fabric Finishing subcategories was found to be warranted. Subcategory 4 wastewater characteristics were found to be influenced also by the amount of desizing performed. Therefore, complex processing mills are further broken down based on less than or greater than 50 percent desizing. Although not significant at the 10 percent level, observed differences in COD loadings for Simple vs Complex Knit Fabric Finishing mills made division of this subcategory attractive. Further classification of Hosiery, Carpet, or Stock & Yarn Finishing mills could not be justified.

Wastewater Characteristics and Treatability

Data on wastewater characteristics support subcategorization based on product. Specific water usage rates and wastewater volumes and characteristics are associated with each subcategory selected. In addition, wastewater treatment efficiencies vary somewhat for the different wastes, and thus raw waste characteristics tend to determine attainable effluent quality for each subcategory. A summary of the median raw waste values of the significant parameters for each subcategory and subdivision is provided in Table IV-3. The values provide a general comparison between all subcategories and demonstrate the usefulness of the internal subdivisions established.

Although wastewater concentrations and loadings are variable throughout the industry, the constituents of most textile wastewaters are similar and, in general, these wastewaters are amenable to biological and physicochemical treatment systems of the same general

TABLE IV-2
STATISTICAL SIGNIFICANCE - COMPARISON OF PROCESSING COMPLEXITY
INTERNAL COMPARISONS

Data Base	Comparison	Test Statistic*			
		Water Usage	BOD_5	COD	TSS
Woven Fabric Finishing	Simple vs Complex	NS	NC	5	NC
Woven Fabric, Simple Finishing	LTET** vs GT** 50% Desizing	NC	NS	NS	NS
Woven Fabric, Complex Finishing	LTET vs GT 50% Desizing	NC	2	NS	5
Woven Fabric, Except Complex Finishing GT 50% Desizing	Simple vs Complex LTET 50% Desizing	NC	NC	NS	NC
Woven Fabric, Except Complex Finishing LTET 50% Desizing	Simple vs Complex GT 50% Desizing	NS	1	2	2
Knit Fabric Finishing, Except Hosiery Products	Simple vs Complex	NS	NS	NS	NS
Hosiery Finishing	Simple vs Complex	NS	NS	NS	NS
Carpet Finishing	Simple vs Complex	NS	NS	NS	NS
Stock & Yarn Finishing	Simple vs Complex	NS	NS	NS	NC

* Values indicate level of significance in percent; NS and NC indicate "Not Significant at 10% level" and "Not Compared," respectively.
** LTET = Less Than or Equal To; GT = Greater Than

TABLE IV-3
MEDIAN RAW WASTE VALUES - STATISTICAL TESTING STUDIES

Subcategory	Water Usage (l/kg)	Water Usage (gal/lb)	BOD5 (kg/kkg)	COD (kg/kkg)	TSS (kg/kkg)
1. Wool Scouring	11.7	1.4	41.8	128.9	43.1
2. Wool Finishing	283.6	34.1	59.8	204.8	17.2
3. Low Water Use Processing	9.2	1.1	2.3	14.5	1.6
4. Woven Fabric Finishing:					
a. Simple Processing	78.4	9.4	22.6	92.4	8.0
b. Complex Processing	86.7	10.4	32.7	110.6	9.6
c. Complex Processing Plus Desizing	113.4	13.6	45.1	122.6	14.8
5. Knit Fabric Finishing:					
a. Simple Processing	122.4	14.7	23.4	81.1	6.6
b. Complex Processing	122.4	14.7	23.4	115.4	6.6
c. Hosiery Products	69.2	8.3	26.4	89.4	6.7
6. Carpet Finishing	46.7	5.6	25.6	82.3	4.7
7. Stock & Yarn Finishing	100.1	12.0	20.7	62.7	4.6
8. Nonwoven Manufacturing	40.0	4.8	6.7	38.4	2.2
9. Felted Fabric Processing	212.7	25.5	70.2	186.0	64.1

type. Wool Scouring facilities are the only major group of mills with extremely different wastes, and wastewater treatment schemes for these mills may differ somewhat from those in the rest of the industry. However, because most textile wastes can be treated in the same general manner, subcategorization of the textile industry based on wastewater treatability is not justified. Also, because of the similarity in the treatability of most textile wastewaters, associated costs and energy requirements of water pollution control technology are unsatisfactory as a basis for subcategorization.

Size and Age

Textile operations range in size from small shops to large mills with thousands of employees. In most cases, however, wastewater volume and pollutant load are proportional to size, and size alone has only a minor effect on wastewater characteristics. While size does dictate, to some degree, the types and costs of wastewater treatment technologies, these factors are taken into account in the development of control and treatment alternatives and costs in Sections VII and VIII, and do not constitute a basis for subcategorization of the industry.

Facility age is not a suitable basis for textile subcategorization because age of both facilities and manufacturing equipment varies substantially. New facilities do not necessarily have modern equipment, nor do all old facilities have old equipment. Continuous modernization of facilities and maintenance of equipment can serve to modify the effects of age on wastewater characteristics.

Effects of variations in mill size or mill age due to the manufacture of different products is taken into consideration through subcategorization on a product basis. Comparisons of the test parameters for various ranges of mill size and mill age for Subcategories 4, 5, and 7 are presented in Tables IV-4 and IV-5. The comparisons indicate that neither size nor age significantly affects hydraulic or pollutant loadings in a consistent manner for establishments engaged in similar manufacturing operations.

Location

Mill location, both geographically and locally, may be important in terms of water supply quantity and quality, land availability, treatment efficiency, and wastewater treatment costs, but does not appear to provide a justifiable basis for subcategorization. The effect of geographical location on the test parameters is illustrated in Table IV-6 for Subcategories 4, 5, and 7. From this, it would appear that mills in the central and western portions of the country use less water than those in the eastern United States, although the numbers of mills in the samples are small and may not be fully representative. Water usage rate is highest for mills in the south,

TABLE IV-4
EFFECT OF PRODUCTION SIZE ON TEXTILE WASTEWATER CHARACTERISTICS*

Size Range (1000 lb/day)	Number of Mills	Water Usage Rate (l/kg) Median (Range)	BOD5 (kg/kkg) Median (Range)	COD (kg/kkg) Median (Range)	TSS (kg/kkg) Median (Range)
		Subcategory 4 - Woven Fabric Finishing			
1 - 20	43	83 (4-396)	34 (4-120)	99 (10-301)	11 (1-222)
21 - 50	39	72 (4-508)	25 (4-143)	85 (28-798)	12 (1-177)
Over 50	60	98 (11-235)	35 (4-215)	114 (30-437)	11 (1-47)
		Subcategory 5 - Knit Fabric Finishing			
1 - 20	38	120 (8-417)	20 (4-209)	81 (47-372)	9 (5-292)
21 - 50	41	39 (15-378)	28 (8-138)	84 (18-503)	7 (2-110)
Over 50	30	103 (83-393)	23 (3-85)	115 (51-379)	6 (1-42)
		Subcategory 7 - Stock & Yarn Finishing			
1 - 20	57	112 (8-613)	24 (3-113)	75 (21-380)	5 (1-478)
21 - 50	36	111 (3-558)	25 (1-113)	65 (2-255)	4 (1-35)
Over 50	24	64 (5-303)	17 (3-38)	62 (13-110)	5 (1-10)

* Based on data from detailed industry survey.

TABLE IV-5
EFFECT OF MILL AGE ON TEXTILE WASTEWATER CHARACTERISTICS*

Age Range (Years)	Number of Mills	Water Usage Rate (1/kg) Median (Range)	BOD5 (kg/kkg) Median (Range)	COD (kg/kkg) Median (Range)	TSS (kg/kkg) Median (Range)
		Subcategory 4 - Woven Fabric Finishing			
1 - 15	31	101 (5-247)	24 (4-120)	96 (43-267)	8 (2-177)
16 - 40	47	89 (4-277)	43 (4-189)	121 (13-388)	13 (4-62)
Over 40	56	82 (15-508)	39 (6-215)	119 (31-798)	11 (1-222)
		Subcategory 5 - Knit Fabric Finishing			
1 - 15	53	124 (1-378)	26 (3-52)	115 (51-173)	7 (1-20)
16 - 40	24	115 (15-417)	23 (8-209)	88 (33-372)	6 (2-292)
Over 40	27	103 (13-388)	28 (9-138)	110 (18-503)	9 (3-108)
		Subcategory 7 - Stock & Yarn Finishing			
1 - 15	32	104 (3-448)	21 (1-113)	71 (2-380)	3 (1-26)
16 - 40	32	105 (8-433)	18 (3-57)	54 (21-306)	5 (1-35)
Over 40	37	105 (11-613)	21 (3-76)	72 (13-219)	5 (1-23)

* Based on data from detailed industry survey.

TABLE IV-6

EFFECT OF GEOGRAPHICAL LOCATION ON TEXTILE WASTEWATER CHARACTERISTICS*

Geographical Location	Number of Mills	Water Usage Rate (l/kg) Median (Range)	BOD5 (kg/kkg) Median (Range)	COD (kg/kkg) Median (Range)	TSS (kg/kkg) Median (Range)
		Subcategory 4 - Woven Fabric Finishing			
Northeast	45	82 (13-428)	34 (6-109)	103 (28-240)	12 (1-222)
Southeast	89	101 (4-508)	31 (4-215)	113 (10-798)	10 (1-177)
Central & West	9	28 (4-99)	63 (47-78)	153 (one mill)	50 (35-62)
		Subcategory 5 - Knit Fabric Finishing			
Northeast	39	98 (1-388)	20 (3-138)	88 (33-503)	7 (1-108)
Southeast	67	127 (20-417)	28 (4-209)	101 (18-379)	6 (1-292)
Central & West	3	92 (13-237)	No Data	110 (48-173)	16 (11-20)
		Subcategory 7 - Stock & Yarn Finishing			
Northeast	29	83 (8-506)	17 (3-113)	76 (23-306)	4 (1-478)
Southeast	82	108 (3-613)	24 (1-113)	63 (2-380)	5 (1- 26)
Central & West	6	48 (15-240)	9 (4-25)	46 (26-73)	4 (2-7)

* Based on data from detailed industry survey.

Note:

Northeast - CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT
Southeast - AL, FL, GA, KY, MS, NC, SC, TN, VA, WV
Central & West - All Other States

possibly because water is still a plentiful commodity in that area. Pollutant loadings, especially between mills in the north and those in the south, do not vary in a consistent manner and this, coupled with the variability, complexity, and overriding effects of previously cited factors, prevents location from being sufficient to define or substantiate subcategories.

Plant Operating Characteristics

The effects on water usage of automation, number of employees, and work schedule were investigated at mills performing similar manufacturing operations. Only the number of shifts (work schedule) had any impact on water usage. The need to balance production from operations that take place at different rates often results in significant differences in water usage between shifts. Mills operating three shifts per day have considerably higher water usage per unit of production than those operating one or two shifts, and investigations showed a correlation between the number of shifts and complexity of operations performed. The subdivisions within the selected subcategorization account for this characteristic.

SUBCATEGORY DESCRIPTIONS AND RATIONALE BEHIND SELECTION

Subcategory 1 - Wool Scouring

This subcategory covers facilities that scour natural impurities from raw wool and other animal hair fibers as the majority of their processing. Integrated mills that perform Wool Scouring and other finishing operations should apply the applicable Wool Scouring effluent limitations to the Wool Scouring production and the other finishing production to applicable effluent limitations covering that production in order to calculate discharge allowances.

Wool and other animal hair fibers must be thoroughly cleaned by alkali and detergent scouring before they can be converted into textile products. A complete description of the wool scouring process is given in Section III.

Wool scouring is conveniently separated from other segments of the textile industry because wool and other animal hair fibers require extensive preliminary cleaning. The raw wastes (See Section V) are considerably stronger than those of other subcategories.

Subcategory 2 - Wool Finishing

This subcategory covers facilities that finish fabric, a majority of which is wool, other animal hair fiber, or blends containing primarily wool or other animal hair fibers, by employing any of the following processing operations on at least five percent of their total production: carbonizing, fulling, bleaching, scouring (not including raw wool scouring), dyeing and application of functional finish chemicals. Mills that primarily finish stock or yarn of wool, other animal hair fibers, or blends containing primarily wool or other animal hair fibers and that perform carbonizing are included in this subcategory and wool stock or yarn mills that do not perform carbonizing and scouring are covered under Subcategory 7, Stock & Yarn Finishing.

The processes comprising a typical wool finishing operation, which include carbonizing, fulling, fabric scouring, and dyeing, are described in Section III. Wool finishing is differentiated from other finishing categories because of the manufacturing processes (principally carbonizing and fulling) and dyes and other chemicals associated with wool operations. As a result, wool finishing operations generate high volume wastes with pH fluctuations and oil & grease.

Subcategory 3 - Low Water Use Processing

Low water use processing operations include establishments primarily engaged in manufacturing greige goods, laminating or coating fabrics, texturizing yarn, tufting and backing carpet, producing tire cord fabric, and similar activities in which either cleanup is the primary water use or process water requirements are small, or both.

Subcategory 4 - Woven Fabric Finishing

This subcategory covers facilities that primarily finish fabric, a majority of which is woven, by employing any of the following processing operations on at least five percent of their production: desizing, scouring, bleaching, mercerizing, dyeing, printing, and application of functional finish chemicals. Integrated mills that finish a majority of woven fabric along with griege manufacturing or other finishing operations such as yarn dyeing are included in this subcategory and total finishing production should be applied to the applicable Woven Fabric Finishing effluent limitations to calculate discharge allowances. Denim finishing mills are also included in this category. Woven fabric composed primarily of wool is covered under Subcategory 2 - Wool Finishing.

A wide variety of processes are used in finishing woven fabric, and, in terms of cumulative flow this subcategory is the largest. Processes that may be employed are described in Section III and include desizing, scouring, bleaching, mercerizing, dyeing, printing, and application of functional finish chemicals. Many finishing facilities also perform weaving, but the added hydraulic and pollutant loadings from slasher equipment cleanup are insignificant compared to the finishing wastes.

Desizing is a major contributor to the BOD load in woven fabric finishing. This results in a major difference in waste characteristics between woven and knit fabric finishing, and the amount of desizing practiced is responsible for differences in the waste characteristics within the Woven Fabric Finishing subcategory as well. In addition, the number of processes performed at a particular mill may vary from merely scouring or bleaching to all of those previously listed. Consequently, it is important to further subdivide this subcategory.

Simple Processing. This Woven Fabric Finishing subdivision covers facilities that perform fiber preparation, desizing, scouring, functional finishing, and/or one of the following processes applied to more than five percent of total production: bleaching, dyeing, or printing. This subdivision includes all Woven Fabric Finishing mills that do not qualify under either the Complex Processing or Complex Processing plus desizing subdivisions.

Complex Processing. This Woven Fabric Finishing subdivision covers facilities that perform fiber preparation, desizing of less than 50 percent of their total production, scouring, mercerizing, functional finishing, and more than one of the following, each applied to more than five percent of total production: bleaching, dyeing, and printing.

Complex Processing Plus Desizing. This Woven Fabric Finishing subdivision covers facilities that perform fiber preparation, desizing of greater than 50 percent of their total production, scouring, mercerizing, functional finishing, and more than one of the following, each applied to more than five percent of total production: bleaching, dyeing, and printing.

Subcategory 5 - Knit Fabric Finishing

This subcategory covers facilities that primarily finish fabric made of cotton and/or synthetic fibers, a majority of which is knit, by employing any of the following processing operations on at least five percent of their production: scouring, bleaching, dyeing, printing, and application of lubricants, antistatic agents, and functional finish chemicals. Integrated mills that finish a majority of knit fabric along with greige manufacturing or other finishing operations such as yarn dyeing are included in this subcategory and total finishing production should be applied to the applicable Knit Fabric Finishing effluent limitations to calculate discharge allowances.

Basic knit fabric finishing operations are similar to those in the Woven Fabric Finishing subcategory and may include scouring, bleaching, dyeing, printing, application of lubricants, antistatic agents, and functional finish chemicals. Knitting is performed in conjunction with finishing at most of these facilities. Desizing is not required in knit fabric finishing and mercerizing is uncommon in practice. The generally lower waste loads of the subcategory can be attributed to the absence of these processes.

As with woven fabric finishing, the number of processes performed at a mill may vary considerably. In addition, hosiery manufacture is distinct in terms of manufacturing and raw wastewater characteristics. Consequently, internal subdivision is required for this subcategory.

Simple Processing. This Knit Fabric Finishing subdivision covers facilities that perform fiber preparation, scouring, functional finishing, and/or one of the following processes applied to more than five percent of total production: bleaching, dyeing, or printing. This subdivision includes all Knit Fabric Finishing mills that do not qualify under either the Complex Processing or Hosiery Products subdivisions.

Complex Processing. This Knit Fabric Finishing subdivision covers facilities that perform fiber preparation, scouring, functional finishing, and/or more than one of the following processes each applied to more than five percent of total production: bleaching, dyeing, or printing.

Hosiery Products. This Knit Fabric Finishing subdivision covers facilities that are engaged primarily in dyeing or finishing hosiery of any type. Compared to other Knit Fabric Finishing facilities, Hosiery Finishing mills are generally much smaller (in terms of wet production), more frequently employ batch processing, and more often consist of only one major wet processing operation. All of these factors contribute to their lower water use and much smaller average wastewater discharge.

Subcategory 6 - Carpet Finishing

This subcategory covers facilities that primarily finish textile-based floor covering products, of which carpet is the primary element, by employing any of the following processing operations on at least five percent of their production: scouring, bleaching, dyeing, printing, and application of functional finish chemicals.

Integrated mills that finish a majority of carpet along with tufting or backing operations or other finishing operations such as yarn dyeing are included in this subcategory and total finishing production should be applied to the applicable Carpet Manufacturing effluent limitations to calculate discharge allowances. Mills that only perform carpet tufting and/or backing are covered under Subcategory 3 - Low Water Use Processing.

Processes comprising a typical carpet manufacturing operation are described in Section III. Carpet Manufacturing is a distinct segment of the textile industry because of the lower degree of processing required and the typically weaker wastes that result.

Subcategory 7 - Stock & Yarn Finishing

This subcategory covers facilities that primarily finish stock, yarn, or thread of cotton and/or synthetic fibers by employing any of the following processing operations on at least five percent of their production: scouring, bleaching, mercerizing, dyeing, or application of functional finish chemicals. Thread processing includes bonding, heat setting, lubrication, and dressing, but these processes are basically dry and do not generate much wastewater. Facilities finishing stock, or yarn, principally of wool also are covered if they do not perform carbonizing as needed for coverage under Subcategory 2 - Wool Finishing. Denim finishing is included under Subcategory 4 - Woven Fabric Finishing.

Typical stock & yarn finishing may include scouring, bleaching, mercerizing, dyeing, or functional finishing. Stock dyeing is basically tub dyeing, but yarn or thread dyeing may include any of the following methods: skein, package, space, or beam. As a result of process differences, the concentrations of the pollutants in the raw wastewater in this subcategory are lower than those found in most other subcategories.

Subcategory 8 - Nonwoven Manufacturing

This subcategory covers facilities that primarily manufacture nonwoven textile products of wool, cotton, or synthetics, singly or as blends, by mechanical, thermal, and/or adhesive bonding procedures. Nonwoven products produced by fulling and felting processes are covered in Subcategory 9 - Felted Fabric Processing.

The Nonwoven Manufacturing subcategory includes a variety of products and processing methods. The processing is dry (mechanical and thermal bonding) or low water use (adhesive bonding) with the major influence on process-related waste characteristics resulting from the cleanup of bonding mix tanks and application equipment. Typical processing operations include carding, web formation, wetting, bonding (padding or dipping with latex acrylic or polyvinyl acetate resins) and application of functional finish chemicals. Pigments for coloring the goods are usually added to the bonding materials.

Subcategory 9 - Felted Fabric Processing

This subcategory covers facilities that primarily manufacture nonwoven products by employing fulling and felting operations as a means of achieving fiber bonding.

Wool, rayon, and blends of wool, rayon, and polyester are typically used to process felts. Felting is accomplished by subjecting the web or mat to moisture, chemicals (detergents), and mechanical action. Wastewater is generated during rinsing steps that are required to prevent rancidity and spoilage of the fibers. Typical felted fabric processing operations are discussed in Section III.

SECTION V

WASTE CHARACTERISTICS

BACKGROUND

The subcategorization presented in Section IV provides the most rational subdivision of the textile industry for the purpose of establishing effluent limitations guidelines, new source performance standards, and pretreatment standards for existing and new sources. The methods used to gather and report waste characteristics for the textile industry, and summaries of those characteristics relative to the subcategories established in Section IV, are presented in this section. The wastes are characterized in terms of quantity (cu m/day), concentrations (mg/l), and pollutant loadings (kg/kkg of product) for the conventional and non-conventional pollutants, and concentrations (ug/l) for the toxic pollutants. Quantity of discharge, water use, and conventional and non-conventional pollutant data were, for the most part, acquired from the records of industry-owned-and-operated treatment plants, Federal and state water pollution control monitoring reports, records of publicly owned treatment works (POTW), and a field sampling program. Toxic pollutant data were not readily available and acquisition required a field sampling program.

CONVENTIONAL AND NON-CONVENTIONAL POLLUTANTS

Past studies of the textile industry by EPA (1, 3) and others (4) have established a list of pollutant parameters that are useful in characterizing the wastewaters from the industry. The list includes both conventional and non-conventional pollutants, and is as follows:

Conventional

Biochemical Oxygen Demand (BOD)
Total Suspended Solids (TSS)
Oil & Grease
pH

Non-Conventional

Chemical Oxygen Demand (COD)
Total Phenols
Sulfide
Color

Chromium is an additional pollutant that is now classified as toxic and included on the list of 129 toxic pollutants discussed below in this section. Since historical data are available for this parameter, they are presented here with the conventional and non-conventional pollutants.

Even though the above parameters are recognized as significant in textile mill wastewaters, monitoring practices across the industry are, at best,

inconsistent. National Pollutant Discharge Elimination System (NPDES) permits dictate the parameters to be monitored by these facilities, but in many cases, permit requirements are outdated. For mills discharging wastewaters to POTW, monitoring requirements range from none, which is the typical case, to very complete programs. The majority of these mills pay for wastewater disposal based on a local charge factor per unit of water consumption and monitoring of wastewater constituents is not regularly carried out.

In order to achieve the best possible characterization of the wastes from each subcategory of the industry, mills believed to be potential dischargers of wastewater were contacted regarding the availability of historical data. Based on the contacts, 637 mills were sent a detailed questionnaire requesting that they provide representative monitoring results or information about where such data could be obtained. Data for 1976 was specifically requested in order to obtain a consistent and up-to-date data base.

Data considered useful in developing raw waste characteristics were received for 447 mills. Similarly, data from 75 mills were considered useful in developing BPT effluent characteristics.

Discussion of Raw Wastewater Characteristics

The raw waste characteristics for the textile industry in general reflect the products and the methods employed to manufacture them. Because there is such a diversity in products, in processing, in raw materials, and in process control, there is a wide range in the characteristics. The variation extends vertically within each subcategory, as well as horizontally between the subcategories. Non-process-related variables such as raw water quality and discharge of non-process-related wastes (sanitary, boiler blow-down, cooling water, etc.) contribute to this lack of uniformity.

In Section III, the typical wet processing operations responsible for the wastewater discharged by the textile industry were introduced and fully discussed. In Section IV, the selected subcategories were presented and the basis for their selection fully explained. The discussions that follow relate the processing and raw waste characteristics for each subcategory and explain the source(s) of the pollutants specific to each.

Subcategory 1 - Wool Scouring

Wool scouring waste contains significant quantities of natural oils, fats, suint, and adventitious dirt that, even after in-process grease recovery steps, cause the characteristics to be distinctly different from those of the other subcategories. These materials are collectively responsible for high concentrations and quantities of BOD_5, COD, TSS, and oil & grease. Since the natural fat is technically a wax, it is not readily biodegradable and must be removed by physical or chemical treatment.

According to Trotman (10), a typical dirty wool might consist of 33 percent keratin (wool protein), 26 percent dirt, 28 percent suint, 12 percent fat, and 1 percent mineral matter. The constituents are different for the wool from different breeds of sheep, and it is generally stated that raw wool may contain between 30 and 70 percent impurities.

Sulfur, phenolics, and other organic compounds are brought in with the wool. Phenolics are derived from sheep urine, feces, blood, tars, branding fluids, and insecticides used in sheep-dips. Sulfur makes up approximately 3 to 4 percent of clean keratin and enters the waste stream as fiber (10).

Wool scouring is generally performed in a series of scouring bowls using a counterflow process. The concentration of soap or detergents and alkali (generally sodium carbonate) is about 1 percent total. The pollutional contribution of these scouring materials is insignificant compared to the residual materials scoured from the stock fiber. Complete purification of the wool is not practical, and it is usually accepted that the scouring has been satisfactory if the wool contains less than 1/2 percent of oil (10).

Wastewater from the wool scouring process is usually brown, thickly turbid, and noticeably greasy. It is strongly alkaline and very putrescible.

Subcategory 2 - Wool Finishing

Wool finishing wastes are typically high volume, low concentration wastes (for the conventional pollutant parameters) that, in terms of mass loadings, contribute large quantities of conventional pollutants per unit of production. The non-conventional pollutants (sulfide and color) and the toxic pollutants that have been historically monitored (phenol and chromium) are both high in concentration and quantity. These conditions can be attributed to the numerous steps required in processing and finishing wool yarn and wool fabric and to the wide variety of chemicals used.

The pollutional contributions of each of the major wool finishing steps are detailed below.

Heavy Scour. Even after effective raw grease wool scouring, wool fiber contains a small amount of grease and foreign material. Also, oil (2 to 5 percent by weight) is often added prior to spinning to ensure satisfactory lubrication. All of these materials must be removed before finishing can be performed and to prevent future degradation of the wool fiber by bacteriological action.

The heavy scour process consists of washing the fabric with detergents, wetting agents, emulsifiers, alkali, ammonia, or various other agents to remove the foreign and applied materials. Fibers used to manufacture fancy goods are dyed in the stock state and undergo heavy scour prior to the stock dyeing step. Piece-dyed goods are scoured in the fabric state before the dyeing step; the weight, foreign material content, and degree of felting of the fabric all have a direct bearing on the degree of scouring required.

Heavyweight, closely woven fabrics with a high percentage of recycled wool require very heavy detergents, long wash times, and extensive rinsing periods. High organic and hydraulic loadings are associated with these types of fabric. Light, open goods with a low percentage of wool generally scour more easily with lighter detergents, shorter wash times, and less rinsing, resulting in lower organic and hydraulic discharges.

Because some woolen mills produce only heavyweight fabric, some only lightweight fabric, and some both, it is apparent that considerable hydraulic and organic fluctuations can exist from the heavy scour process.

Carbonizing. Carbonizing does not contribute greatly to the strength of wool finishing wastes but, because of the rinsing steps used to neutralize the acid taken up by the fabric, does add significantly to the hydraulic load. As discussed in Section III, carbonized vegetable matter is removed as a solid waste and only the residual sulfuric acid and neutralizing agents (generally sodium carbonate) enter the waste stream. The acid bath must be dumped when it becomes too contaminated for efficient carbonization and the acid taken up by the fabric must be neutralized to prevent damage to the wool fibers.

The wastewaters from the carbonizing process are typically acidic, low in organic content, and high in total solids.

Fulling. Fulling, like carbonizing, does not contribute significantly to the strength of the wool finishing waste but adds to the hydraulic load. Wastewater is generated during the washing and rinsing steps, which are required to prevent rancidity and wool spoilage, and when the water bath (wet fulling only) is dumped. If alkali fulling is employed, the rinse streams will contain soap or detergent, sodium carbonate, and sequestering agents (phosphate compounds). If acid fulling is also employed, sulfuric acid, hydrogen peroxide, and small amounts of metallic catalysts (chromium, copper, or cobalt) also will be present.

Bleaching. Bleaching is performed on woolens, but to a lesser degree than on cotton goods. Only 40 percent of the woolen mills that returned detailed surveys practice bleaching. Those that do, do so on 20 percent or less of their production. Hydrogen peroxide is generally used because sodium and calcium hydrochloride discolor and damage wool fibers. The volume of waste from hydrogen peroxide bleaching of wool is generally low (1 to 3 gal/lb of product) and the BOD contribution is usually less than one percent of that for the total typical wool finishing process. The waste loads for other conventional parameters are generally very small.

Dyeing. The typical dyeing processes for the industry in general are discussed in Section III. As noted in that discussion, some of the dyes and dye chemicals used for wool goods are specific to the wool fiber. The acid and metalized dyes are commonly used, while mordant and fiber reactive dyes are used to a small extent. Because of the recognized hazards of chromium entering the waste stream, the use of mordant dyes has greatly diminished and they presently are used only if exceptional fastness is mandatory.

In sensitive dyeing, a pre-scour step is often used. Detergents and wetting agents are added, the scouring performed, and the fabric thoroughly rinsed. The waste generated contributes to the hydraulic load but adds little to the strength.

For acid dyes, the main consideration is to create a pH value suitable to the type of dye in use. The ingredients, in addition to the dyes, include Glauber's salt crystals ($Na_2SO_4 - 10H_2O$), sulfuric acid, anformic acid.

The metalized dyes, which are very fast and have a very high affinity for wool even under mildly acidic conditions and at low temperatures (below 110°C), are often used on 100 percent wool fabric. These dyes are almost completely exhausted so only a small quantity of metallic ions (chromium) enters the waste stream.

Blends of wool and synthetic fibers are sometimes dyed in a single bath and sometimes dyed in two separate baths. When two baths are used, dyes specific to each fabric type are used and the hydraulic load can increase by 50 percent.

In each type of dyeing the fabric is cooled with clear water and thoroughly rinsed; both steps add significantly to the hydraulic load.

Subcategory 3 - Low Water Use Processing

Low water use processing refers, almost exclusively, to facilities that perform weaving or adhesive-related processing. Regardless of mill size, process-related wastewaters from both types of mills are typically very low in volume. The only mills with large flows are those engaged in water-jet weaving and mills discharging large volumes of cooling or other non-process water. Where process-related wastewater is a large portion of the total discharge, the wastewater characteristics are determined primarily by the slashing process (conventional weaving), the weaving process (water-jet weaving mills), or the dipping, padding, or saturating process (adhesive-related mills). The pollutional contribution of these processes is discussed below.

Slashing. The slashing operation (see Section III) consists of coating yarn with sizing compounds prior to weaving. At conventional weaving mills, slashing is generally the only source of process wastewater. Wastewater results from spillage in the size mixing area, dumps of excess sizing, and cleanup of the slasher and mixing equipment. Among the components that are used in sizing formulations and that may enter the waste stream are the sizing compounds (starch, PVA, CMC, PAA), wax or tallow, wetting agents, softeners, penetrants, plasticizers, fungicides, bacteriostats, and other preservatives. Sizing formulations are typically high in COD and, if starch is the primary agent, the BOD is also high. In general, the wastes from the slashing operation are highly diluted by non-process wastewater, such as sanitary sewage, boiler blowdown, and non-contact cooling water, generated at these mills.

Water-Jet Weaving. Water-jet looms are a special type of shuttleless loom that use a jet of water to propel the filling yarns during the weaving operation. Although not widely practiced at present, water-jet weaving is becoming more popular. Each type of water-jet loom has different water requirements, and discharges from the different machines were reported to range from less than 3,785 l/day (100 gpd) up to 37,850 l/day (1000 gpd). The water drains from beneath the machines and may contain sizing chemicals and contaminants collected from the fiber. However, chemical sizing requirements are less than with conventional looms since the water has certain lubricating properties. Most of the wastewater from greige mills that employ water-jet weaving comes from this process.

Adhesive Processing. Adhesive processing (see Section III) includes operations such as bonding, laminating, coating, and flocking. In all of these operations a continuous adhesive or coating is applied to the material by padding, dipping, saturating, or similar means. Wastewater occurs as a result of equipment cleanup, rinsing, overspraying, or spillage. Polyvinyl chloride from coating or latex compounds from bonding, laminating, or flocking are likely to be the chief constituents of these wastewaters. Latex wastes may be high in COD and suspended solids. Depending on the manufacturing activities, other contaminants may also find their way into adhesive-related processing wastewaters.

Subcategory 4 - Woven Fabric Finishing

The wastewater generated from the finishing of woven fabric is represented by a rather broad range in concentration and mass quantity for the conventional pollutant parameters. The internal subdivisions of this subcategory (Simple Processing, Complex Processing, Complex Processing Plus Desizing) group the estimated 336 mills into three reasonably distinct segments. The bases for the subdivisions are thoroughly discussed in Section IV and a schematic displaying the typical processes employed is presented in Section III.

The differences between the three subdivisions are a function of the complexity of the wet processing. Mills classified in the Complex Processing subdivision perform simple processing plus one or more additional major wet-processing steps. Mills classified in the Complex Processing Plus Desizing subdivision perform complex processing plus desizing on the majority of their production. The typical water use and waste mass loading values are progressively greater for each subsequent subdivision and generally reflect an increase in the same basic pollutant parameters.

The wet-processing employed by a Woven Fabric Finishing mill could include desizing, scouring, bleaching, mercerizing, dyeing, printing, and functional finishing. The pollutional contributions of these processing operations are discussed below.

Desizing. Desizing contributes a significant amount of organic load, some oil & grease, and most of the suspended material found in woven fabric finishing wastewater. Natural starch size is high in BOD while the synthetic sizing agents, which tend to be less biodegradable during treatment unless exposed to an acclimated biological environment, result in increased COD. Over an extended period (such as the 20 days required for the standard BOD_{20} test), however, the synthetic sizing agents can exert a substantial oxygen demand. Depending on the fabric type, desizing can contribute 50 percent or more of the total solids resulting from the finishing of woven fabrics (1). For the average Woven Fabric Finishing mill processing 100 percent cotton goods with starch used as the sizing agent, the desizing waste will generally constitute about 16 percent of the total wastewater volume, 45 percent of the BOD, 36 percent of the total solids, and 6 percent of the alkalinity (12).

Synthetic sizing agents such as PVA, CMC, and PAA are soluble in water and can be removed from woven fabric without difficulty. Starch is not readily soluble and must be hydrolyzed into a soluble form by the action of special enzymes or acid solutions before removal. Enzymatic removal generates starch solids, fat, wax, enzymes, sodium chloride, and wetting agents. The waste contains organic and inorganic dissolved solids, suspended solids, and some oil & grease. It has a pH of 6 to 8, and is light in color. Sulfuric acid removal generates starch solids, fat, wax, and sulfuric acid. The wastes also contain organic and inorganic dissolved solids, suspended solids, and some oil & grease. It has a pH of 1 to 2 and is relatively light in color.

The Complex Processing Plus Desizing subdivision of Subcategory 4 was established principally because of the significant waste contribution of the desizing operation.

Scouring. Scouring of cotton and cotton-synthetic fiber blends generate waste liquors that are strongly alkaline (pH greater than 12), dark in color from cotton impurities, and high in dissolved solids. The liquors contain significant quantities of oil & grease and some suspended solids that are removed as impurities in the cotton fiber. Besides sodium hydroxide, of which a 2 percent solution typically is used, phosphate, chelating agents, and wetting agents may be used as auxiliary scouring chemicals. For the typical finishing mill processing 100 percent cotton goods, the scouring waste will generally constitute about 19 percent of the total wastewater volume, 16 percent of the BOD, 43 percent of the total solids, and 60 percent of the alkalinity (12).

Synthetic fibers are relatively free of natural impurities so they require much less vigorous scouring. They experience low moisture regain so static electricity can be a problem during processing. To minimize this problem, antistatic materials are applied to the yarns; these agents also serve as lubricants in sizing compounds. Compounds commonly used are PVA, styrene-base resins, polyalkylene glycols, gelatine, PAA, and polyvinyl acetate. These compounds become a source of water pollution when they are removed from the fabrics during scouring. In general, a milder sodium carbonate solution and a surfactant will suffice in scouring synthetics.

Bleaching. Cotton bleaching may be accomplished with hypochlorite, hydrogen peroxide, chlorine dioxide, sodium perborate, peracidic acid, or other oxidizing agents. Reducing agents may also be used, although almost invariably, the oxidizing agents give a more permanent white. Today, most of the cotton bleaching is done with hydrogen peroxide or hypochlorite, either in kiers or on a continuous range; hydrogen peroxide is the preferred oxidizing agent and the continuous range the most efficient bleaching method.

Bleaching of cellulosic regenerated fibers is accomplished using the same methods as for cotton; however, there is less coloring matter to remove so the severity of the process can be decreased. Polyester and polyacrylonitrile fibers are not often bleached unless part of a cotton-synthetic fiber blend.

Hydrogen peroxide bleaching contributes very small waste loads, most of which are inorganic (sodium silicate, sodium hydroxide, and sodium phosphate) and organic (surfactants and chelating agents) dissolved solids. A low level of suspended solids (fibers and natural impurities) will be present when goods containing cotton are bleached.

Mercerization. Mercerization is practiced to increase the tensile strength of the cotton fiber and to increase its affinity for dyes (see Section III). Essentially, the process amounts to saturating the fabric with sodium hydroxide (usually a 25- to 30-percent solution), allowing sufficient residence time for interaction, and washing the fabric to remove the excess caustic.

Mercerization wastes are predominantly the sodium hydroxide used in the process, diluted as a result of the washing step. The waste stream contains high levels of dissolved solids and may have a pH of 12 to 13. Depending on whether mercerization is practiced before or after bleaching, small amounts of foreign material and wax may be removed from the fiber and will appear as suspended solids and oil & grease. In total, mercerization has been found to contribute about 1 percent of the BOD load generated during the processing of 100 percent cotton woven fabric (14).

Today, with synthetics and cotton-synthetic blends replacing 100 percent cotton fabric, mercerization is practiced less often. Most of the mills that do utilize the process have found it economically attractive to recover sodium hydroxide for reuse. Consequently, the waste contribution from the process has become even less significant at many mills.

Dyeing. Dyeing is without question the most complex of all the wet-finishing operations for all of the applicable textile subcategories. There are 9 basic classifications of dyes, according to application, and approximately 17 types according to use by the textile industry (10). There are thousands of individual dyes. Besides the dyestuff itself, various other chemicals are used to help deposit the dye or to develop the color. Chemicals that may be employed include acids, bases, salts, wetting agents, retardants, accelerators, detergents, oxidizing agents, reducing agents, developers, and stripping agents.

A complete and detailed discussion of the various dyes and dyeing methods is provided in Section III.

Woven fabric is usually dyed as piece goods with batch or continuous dye equipment. The batch equipment can be either the atmospheric type or the pressure type; continuous dye equipment is operated under atmospheric pressure conditions. Atmospheric dyeing generally requires greater amounts of auxiliary chemicals to achieve the desired results. Since most of these chemicals are not retained in the final product but are discarded after they have served their purpose, atmospheric dyeing customarily results in increased waste loadings.

Depending on the type(s) of fabric, the type(s) of dyes used, the type(s) of equipment employed, and the efficiency of the process(es), the waste stream from the dyeing of woven fabric may contain any combination of the dyes and auxiliary chemicals. It can contribute substantially to the total waste load and is responsible for most of the waste volume. Color is an obvious adverse pollutant and high levels of dissolved solids are present. Suspended solids are relatively low.

For various Woven Fabric Finishing mills that process 100 percent cotton, the BOD contribution resulting from the dyeing process was found to vary from 1.5 to 30 percent of the total (14). Carriers, which are essential for dyeing polyester, can result in an even greater BOD contribution when cotton/polyester blends and pure polyesters are being processed.

Printing. Printing is generally accomplished at the same stage in woven fabric finishing as is dyeing. The fabric goes through the preliminary cleaning and conditioning steps and is printed using one of several methods. Woven fabric may be dyed and printed, in which case printing is performed last. A complete discussion of the types of printing and equipment used to perform them is provided in Section III.

Printing has often been referred to as localized dyeing, and as such, the same basic dyestuffs are used in both processes. Dyes are applied as liquid, while a paste is used in printing. In addition to the dyestuff and auxiliary chemicals discussed under "Dyeing", a thickener is used to give the print paste the desired viscosity. Gums serve as thickeners and those commonly used include locust bean, guar, alginate, starch, and combinations of these. Urea, thiourea, and glycols are also used in many print formulations.

Printing wastes are comparable in constituents to dye wastes, although the volumes are much lower and the concentrations greater. The thickeners contribute to the BOD, and solvents used to prepare pigments and clean pigment application equipment are often present.

Printing pigments will contribute some suspended solids when the fabric is rinsed, although much of the waste from printing comes from the cleaning of make-up tanks and process equipment.

Functional Finishing. The functional finishes represent a large group of chemical treatments that extend the function of a fabric by making it resist creasing, water, stains, rot, mildew, moths, bacteria, and other undesirable items. They are more often applied to the natural fibers (cotton and wool) and are therefore quite prevalent in the finishing of woven fabrics. As would be expected from processes that provide such diverse effects, the range of chemicals used is very broad. For resin treatment, a urea-formaldehyde-glyoxal compound (DMDHEU), a fatty softener, and a catalyst (zinc nitrate, magnesium chloride) are used together. Water repellents include silicones, fluorochemicals, and fatty materials, each generally applied with a catalyst. Soil release treatments include special acrylic polymers and fluorochemicals.

These finishes are generally applied by impregnation of the fabric followed by squeezing to retain the desired amount of add-on. The moist material is dried and then heat cured. The cured fabric is frequently packed for shipment without rinsing. Most resin-treated goods are pre-cured in finishing.

Waste from resin treatment, water-proofing, flame-proofing, and soil release are small in volume, since the chemicals are applied by padding, followed by drying and curing. The chemicals used are diverse and small amounts of them will enter the mill's waste stream. Some of these finishes do require afterwashing, which increases the volume of water used and quantity of chemicals discharged.

Subcategory 5 - Knit Fabric Finishing

The wastewaters generated from the finishing of knit fabric are, like those from the finishing of woven fabric, represented by a rather broad range in concentration and mass quantity for the conventional pollutant parameters. The typical waste is not generally as great in terms of concentration as woven fabric finishing waste, and the variability from mill to mill is also somewhat less. The internal subdivisions of this subcategory (Simple Processing, Complex Processing, and Hosiery Products) group the estimated 442 wet-processing mills into three distinct segments. As with Woven Fabric Finishing, the subdivisions established for knitted fabric are based on complexity of the operation. The Hosiery Products subdivision was established because the processing in this segment requires less water and less variable amounts and types of process chemicals. The bases for the subdivisions are fully discussed in Section IV and a schematic representing the typical processing sequence for each subdivision, as well as a description of processes, is presented in Section III.

The wet processing employed by a Knit Fabric Finishing mill (Simple Processing and Complex Processing subdivisions) can include various combinations of the following operations: scouring, bleaching, dyeing, and printing. A Hosiery Products mill typically employs scouring, bleaching, and dyeing. Each subdivision might apply chemical coatings during the final finishing step, but only a small amount, if any, of these chemicals enters the waste stream. The impact of these processes on wastewater discharged by Knit Fabric Finishing mills is discussed below.

Sizing, as such, is not applied to knitted goods because the knitting process does not stress the yarn to the same degree as does weaving. Lubricants, generally mineral oils, vegetable oils, synthetic esters, or waxes, are added but these can be removed easily with simple scouring. Thus, desizing is not necessary.

Scouring. Washing or scouring is frequently the first process at Knit Fabric Finishing mills. Knit goods are washed or scoured with detergents, soaps, or solvents to remove natural or artificial waxes, oils and other impurities. The discharge of the scouring or wash solution along with any acquired impurities from knit cotton fabric or blends, will result in a wastewater high in dissolved solids, dark in color from cotton impurities, and containing significant quantities of oil & grease. The scouring or washing of 100 percent synthetic fabrics typically results in a less contaminated waste.

Bleaching. Bleaching of knit fabrics is similar to bleaching of woven fabrics. The bleaching agents used are generally sodium hypochloride or hydrogen peroxide, and the previous discussion in this section on waste characteristics associated with bleaching woven fabrics is also applicable to this subcategory.

Dyeing. The dyeing operation is a major source of wastewater in knit fabric finishing. Beck, beam, and jet dyeing are all commonly employed using either atmospheric or pressure operating modes. Paddle, rotary, or tub dyeing may also be employed, especially for hosiery. Jig dyeing and continuous dyeing are less common. The types of dyestuff, auxiliary chemicals, and conditions employed for dyeing knit goods are essentially the same as for woven goods of comparable fiber composition. The discussion previously presented in this section concerning waste characteristics associated with dyeing woven fabrics is also relevant to knit fabric dyeing and is not repeated here. In knit fabric finishing, rinse liquors are often mechanically extracted. In this step a centrifugal extractor is used to draw water out of the fabric.

Printing. Printing methods used in finishing knit fabrics are similar to the methods used on woven fabrics. Sources and characteristics of the wastes are similar to those previously discussed for the Woven Fabric Finishing subcategory.

Functional Finishing. The functional finishes applied to knit fabrics are essentially the same as those previously noted for woven fabrics. The methods of application are also similar so the same variety of constituents is likely to appear in the waste.

Subcategory 6 - Carpet Finishing

The wastewater volume from carpet mills is typically quite large, although water use (gal/lb of product) is low relative to other subcategories. This is due to the specialized nature of carpet manufacturing and the heavy weight of carpet relative to other textile products. The wet processing employed by a carpet mill can include various combinations of the following operations: scouring, bleaching, dyeing, printing, functional finishing, and backing. Wastes from dyeing and printing are the major contributors to the high flows at these mills, but these processes do not lead to extreme levels of conventional and non-conventional pollutants. Scouring and bleaching are performed very little at carpet finishing mills. Functional finishing and carpet backing make small contributions to the total flow; the latter often results in a latex waste that should be segregated from the rest of the waste discharge for separate treatment. The pollutional contributions of these processes are discussed below.

Scouring/Bleaching. Carpets may be scoured with soaps or detergents to remove processing oils, waxes, and other impurities and prepare them for dyeing or printing. If bleaching is required, the bleaching agents are added after scouring (4). Less than 15 percent of the mills that returned detailed surveys perform scouring, and at all of these the percentage of total production scoured is small (1 to 40 percent with an average of 16 percent). Only three mills that returned detailed surveys perform bleaching; the amount of production reported bleached was 1, 2, and 10 percent, respectively. Thus, scouring and bleaching are seen to have only a minor effect on the characteristics of carpet mill wastewaters.

Dyeing. Nearly all Carpet Finishing mills perform piece dyeing, and the wastewaters are greatly influenced by the dyes used and dye machines employed. Nylon is the major fiber type in the manufacture of carpet, although the use of polyester fiber is also substantial. Other fibers are used by only 5 mills that returned detailed surveys. Dyeing is typically accomplished using atmospheric dye becks, or, to a lesser extent, continuous dye ranges. Only four dye classifications were identified as being used by carpet finishing mills. Acid dyes, dispersed dyes, and cationic dyes are most frequently employed, and small quantities of direct dyes are sometimes used. In addition to these dyestuffs themselves, numerous auxiliary chemicals, such as leveling agents, inorganic compounds, acids, sequestering agents, organic compounds, dispersing agents, and various carriers may also be employed, as discussed in Section III. Since most of these auxiliary chemicals perform a function during the dyeing operation, they do not remain with the carpet. As a result they are found in the waste stream along with excess dyes and contribute substantially to BOD, COD, dissolved solids, and color.

Printing. Carpet is generally printed by rotary, flat bed, warp yarn, or tuft dye equipment. Flat bed printing is the most common method, although even this mode of printing occurs at less than 10 percent of the mills returning detailed surveys. Spray printing techniques, using highly advanced electronically controlled machinery, may play an important role in carpet printing in the future, but at present wastes from carpet printing should not differ substantially from those discussed previously for woven fabric printing.

Functional Finishing. Chemical agents may be applied to carpets after dyeing or printing to impart certain desirable qualities. Chemicals that increase the water repellency, flame or mildew resistance, and soil retardance are sometimes used, as are anti-static agents and softeners. Since these agents are not applied as frequently and are not as numerous as those which might be used in finishing woven fabric, their impact should be less. Nevertheless, these various chemicals will enter the waste stream in small amounts and will have a minor effect on hydraulic and pollutant loadings.

Carpet Backing. The carpet backing process laminates a secondary backing (normally jute or propylene) to the dyed or printed carpet. The adhesive is normally a latex compound, although sometimes a foam backing of urethane or latex is used. The latex used in both foamed and unfoamed backing is not soluble in water, but is used in a highly dispersed form. Waste from this process may be high in suspended solids and COD.

Subcategory 7 - Stock & Yarn Finishing

The volume of wastewater discharged by Stock & Yarn Finishing facilities is comparable to that from mills in other finishing subcategories. The wastes generated are generally not as strong as those found in the other subcategories, and depend substantially on whether natural fibers, blends, or synthetic fibers alone are processed.

The wet processing employed by a Stock & Yarn Finishing mill can include various combinations of the following operations: scouring, bleaching, mercerizing, dyeing, and printing. Bleaching and dyeing are the processes most commonly responsible for wastes in this subcategory. Scouring, mercerizing, and "printing" (space or knit-deknit dyeing) are only performed on a very limited basis. A description of stock & yarn processing, as well as schematics of typical finishing operations, is presented in Section III. The pollutional contributions of the wetprocessing operations are discussed below.

Mercerization. Concentrated caustic solution is used to mercerize cotton yarns at some of the mills in this subcategory. The resulting wastewater has a high pH and contains high levels of dissolved solids.

Bleaching/Scouring. Bleaching is performed on either raw stock or yarn to whiten the fibers and remove any natural colors. Sodium hypochlorite or hydrogen peroxide are typically used for this purpose. The contribution of bleaching on wastewater characteristics has been discussed previously in this section under Subcategory 4. Scouring is employed infrequently at Stock & Yarn Finishing mills and has also been discussed previously under Subcategory 4. Scouring of stock or yarn is typically less severe than scouring woven fabric.

Dyeing/Printing. Stock dyeing is usually performed in a vat or pressure kettle. Yarn dyeing is usually performed by skein or package dyeing methods. A specialty yarn dyeing process, similar to and sometimes referred to as printing, is known as space dyeing. All these methods have been previously discussed in Section III; a discussion of dyes and auxiliary chemicals associated with coloring various fibers is also presented there. The effect of dyeing on waste characteristics is presented in detail earlier in this section under Woven Fabric Finishing. Virtually all dye classes are used in stock & yarn dyeing, and the waste generated will be similar to those generated in dyeing fabric or carpet of the same fiber type.

Subcategory 8 - Nonwoven Manufacturing

The nature of nonwoven manufacturing is such that a typical facility has relatively small hydraulic and pollutant loadings. The wastewater may contain latex and numerous other contaminants. At a few facilities, special manufacturing operations or activities common to other subcategories might be performed with resultant higher water use, but this is the exception rather than the rule. The wastewater aspects of the various nonwoven manufacturing processes are discussed below.

Web Formation. Web formation is a dry operation unless the "wet lay" process is used (see Section III). Since water is used as a transport medium for the fibers in this method, some contaminated wastewater results from this process. This waste is generally dilute, has a pH of 6 to 7, and is slightly milky.

Bonding and Coloring. Bonding is used to impart structural integrity to the nonwoven fabric. Adhesives such as acrylics, polyvinyl acetate resins, or other latex compounds are usually used. Cleanup of applicator equipment and mixing tanks results in small volumes of wastewater contaminated with the adhesives. The function of nonwoven fabrics (i.e. commercial applications, disposable items, etc.) is such that adding color is not always necessary. When color is required, it is generally applied in the form of pigments added to the bonding agents.

Functional Finishing. Chemical treatments to impart flame resistance, water repellency, or mildew resistance are often applied to nonwovens. The methods of application and effects on wastewater characteristics are similar to those previously described for other subcategories.

Subcategory 9 - Felted Fabric Processing

Felted fabric processing typically results in high volume wastes of a generally dilute nature. The wet-processing operations may include felting, dyeing, and functional finishing. The rinses that follow felting (fulling) and dyeing, if employed, result in considerable water use and contribute most of the pollutants. Functional finishing may also make minor contributions to the waste load. The pollutional contribution of the typical wet-processing steps is discussed below.

Felting (Fulling). Fulling of felted fabric is similar to the fulling employed in wool finishing. Detergents, alkali, or acid may all be used, and these constituents along with auxiliary chemicals are discharged whenever baths are dumped. In some cases, neutralization of the acid absorbed by the fabric will be required. The major hydraulic loading comes from the washes or rinses that follow fulling. Hardening is a mechanical pressure process used by some mills prior to fulling to cause the wool to felt. The only waste resulting from this step is from steam or mist condensate that collects on the heavy vibrating metal plates.

Dyeing. Dyeing of felts is not unlike dyeing of other fabrics. Dyes appropriate to the fiber content of the felt are used, along with appropriate amounts of auxiliary chemicals. Together, these materials will contribute to BOD, COD, and dissolved solids loadings in the wastewater.

Functional Finishing. A wide variety of functional finishes and chemical treatments are applied to felts. These chemicals and the methods of application have been previously described. Although functional finishing has only a minor impact on hydraulic loading, a wide variety of chemicals may be introduced into the waste stream.

Characterization of Raw Wastewaters

Statistical summaries of the reported historical raw waste concentrations and loading values for the conventional and non-conventional pollutant parameters are presented in Table B-1 of Appendix B. The summaries provide the minimum, maximum, average, and median values, as well as the number of plants represented for each parameter in each subcategory. The values represent averages for mills for which historical data were obtained. The range in these data demonstrates the high degree of variability that is inherent in the industry.
Water usage rates and total mill wastewater discharge for each subcategory are presented in Table V-1. Discharge values represent the median of the reported values while water usage rates are represented by the range and median of calculated values. Wool scouring, as noted in the table, requires the least water per unit of production. In comparing the values shown, however, it should be kept in mind that raw wool contains between 30 to 70 percent by weight of non-wool materials such as dirt and grease. This material is included when calculating water usage for this subcategory.

In contrast, wool finishing requires the greatest amount of water, principally because of the numerous low temperature rinsing steps that are required to remove residues from the carbonizing, scouring, and bleaching processes and soaps from the fulling process. Detailed descriptions of the process water requirements are provided in Section III.

The median discharge for Complex Knit Fabric Finishing mills (Subcategory 5b) and Wool Finishing mills (Subcategory 2) are the largest, while Hosiery Products mills (Subcategory 5c) and Wool Scouring mills (Subcategory 1) have the smallest median discharge. The greatest flow (28,900 cu m/day) is discharged by a Complex Processing Woven Fabric Finishing mill (Subcategory 4b) and the smallest flow (4 cu m/day) by a Hosiery Products mill (Subcategory 5c) (See Table B-1, Appendix B).

Raw waste concentrations for the conventional and non-conventional pollutant parameters are presented in Table V-2. Values are included for each parameter for which three or more data points are available. The values are the medians of the reported values rounded off for presentation purposes. For the conventional parameters, the median wool scouring discharge is the most concentrated and the median wool finishing discharge is the least concentrated. This is directly related to the fact that the Wool Scouring subcategory and the Wool Finishing subcategory use, respectively, the least and greatest amounts of processing water per unit of production (based on median values and not including Low Water Use Processing, see Table V-1).

TABLE V-1
WATER USAGE AND MILL WASTEWATER DISCHARGE - SUMMARY OF HISTORICAL DATA

Subcategory	Water Usage, l/kg (gal/lb) of Production Min.	Med.	Max.	Discharge, cu m/day (MGD) Median Mill	No. of Mills
1. Wool Scouring	4.2 (0.5)	11.7 (1.4)	77.6 (9.3)	193 (0.051)	12
2. Wool Finishing	110.9 (13.3)	283.6 (34.1)	657.2 (78.9)	1892 (0.500)	15
3. Low Water Use Processing	0.8 (0.1)	9.2 (1.1)	140.1 (16.8)	231 (0.061)	13
4. Woven Fabric Finishing					
a. Simple Processing	12.5 (1.5)	78.4 (9.4)	275.2 (33.1)	636 (0.168)	48
b. Complex Processing	10.8 (1.3)	86.7 (10.4)	276.9 (33.2)	1533 (0.405)	39
c. Complex Processing Plus Desizing	5.0 (0.6)	113.4 (13.6)	507.9 (60.9)	636 (0.168)	50
5. Knit Fabric Finishing					
a. Simple Processing	8.3 (0.9)	135.9 (16.3)	392.8 (47.2)	1514 (0.400)	71
b. Complex Processing	20.0 (2.4)	83.4 (10.0)	377.8 (45.4)	1998 (0.528)	35
c. Hosiery Products	5.8 (0.7)	69.2 (8.3)	289.4 (34.8)	178 (0.047)	57
6. Carpet Finishing	8.3 (1.0)	46.7 (5.6)	162.6 (19.5)	1590 (0.420)	37
7. Stock & Yarn Finishing	3.3 (0.4)	100.1 (12.0)	557.1 (66.9)	961 (0.254)	116
8. Nonwoven Manufacturing	2.5 (0.3)	40.0 (4.8)	82.6 (9.9)	378 (0.100)	11
9. Felted Fabric Processing	33.4 (4.0)	212.7 (25.5)	930.7(111.8)	564 (0.149)	11

Source: Sverdrup & Parcel Textile Industry Wastewater Survey, 1976-77.

TABLE V-2
RAW WASTE CONCENTRATIONS - CONVENTIONAL AND NON-CONVENTIONAL POLLUTANTS
HISTORICAL DATA - MEDIAN VALUES

Subcategory	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	O & G (mg/l)	Phenol (ug/l)	Chromium (ug/l)	Sulfide (ug/l)	Color APHA Units
1. Wool Scouring	2270	7030	3310	580	#	#	#	#
2. Wool Finishing	170	590	60	#	#	#	#	#
3. Low Water Use Processing	293	692	185	#	#	#	#	#
4. Woven Fabric Finishing								
a. Simple Processing	270	900	60	70	50	40	70	800
b. Complex Processing	350	1060	110	45	55	110	100	#
c. Complex Processing Plus Desizing	420	1240	155	70	145	100	#	#
5. Knit Fabric Finishing								
a. Simple Processing	210	870	55	85	110	80	55	400
b. Complex Processing	270	790	60	50	100	80	150	750
c. Hosiery Products	320	1370	80	100	60	80	560	450
6. Carpet Finishing	440	1190	65	20	130	30	180	490
7. Stock & Yarn Finishing	180	680	40	20	170	100	200	570
8. Nonwoven Manufacturing	180	2360	80	#	#	#	#	#
9. Felted Fabric Processing	200	550	120	30	580	#	#	#

Insufficient data to report value.

Source: Table B-1, Appendix B.

Wastewater concentrations are of primary importance in predicting the treatability of a particular waste stream and are used to design, monitor, and control the operation of treatment systems. But alone they do not provide a complete picture of the relative pollutant contributions of each subcategory. Waste loadings, which relate pollutant concentrations and water use to production levels, provide a more suitable means of regulating waste discharges. Median waste loading values for the appropriate pollutant parameters are presented in Table V-3. Again, values are reported for each parameter for which three or more data points are available.

The raw waste loads in Table V-3 offer a more direct comparison of the various subcategories than do raw waste concentrations and, in terms of COD, demonstrate the basis of the subdivision of Subcategories 4 and 5, as outlined in Section IV.

The conventional and non-conventional pollutant data collected in conjunction with the field sampling program were instrumental in filling gaps in the historical data base and helped develop a more complete characterization of the typical wastewater from each subcategory. The data for each mill sampled are presented in Table V-4. With the exception of oil & grease, the data are for composite samples. The samples were collected with automatic sampling equipment over either 8- or 24-hr periods or by combining individual grab samples collected at representative intervals over 8- or 24-hr periods. Alone, the field sampling data do not provide a reliable characterization of the wastewater concentrations because of the limited scope of the sampling procedures and limited number of mills sampled. They are useful, however, to confirm and, in some cases, to supplement the historical data base.

Typical raw waste concentrations for the conventional and non-conventional pollutant parameters, based on both the historical data and the field sampling results, are presented in Table V-5. The values are representative of the typical mill in each subcategory and are those used in developing the treatment technologies and costs in subsequent sections. For several subcategory-parameter combinations, typical values could not be established with sufficient confidence and thus are not presented. Additional sampling would be necessary to establish these values.

Characterization of BPT Effluents

Historical data that were judged to be reliable in terms of sampling methodology, frequency, and duration were available for 75 wet-processing mill treatment facilities that provided Best Practicable Technology (BPT). The types of mills represented by the data include 2 Wool Scouring, 2 Wool Finishing, 7 Simple Processing Woven Fabric Finishing, 7 Complex Processing Woven Fabric Finishing, 18 Complex

TABLE V-3
RAW WASTE LOADS - CONVENTIONAL AND NON-CONVENTIONAL POLLUTANTS
HISTORICAL DATA - MEDIAN VALUES

	Subcategory	BOD	COD (kg/kkg)	TSS	O & G	Phenol	Chromium (g/kkg)	Sulfide
1.	Wool Scouring	41.8	128.9	43.1	10.3	#	#	#
2.	Wool Finishing	59.8	204.8	17.2	#	#	#	#
3.	Low Water Use Processing	2.3	14.5	1.6	#	#	#	#
4.	Woven Fabric Finishing							
	a. Simple Processing	22.6	92.4	8.0	9.1	8.2	4.3	7.6
	b. Complex Processing	32.7	110.6	9.6	3.8	7.7	2.6	12.5
	c. Complex Processing Plus Desizing	45.1	122.6	14.8	4.1	13.1	20.9	#
5.	Knit Fabric Finishing							
	a. Simple Processing	27.7	81.1	6.3	4.0	8.7	7.8	13.0
	b. Complex Processing	22.1	115.4	6.9	3.5	12.0	4.7	14.0
	c. Hosiery Products	26.4	89.4	6.7	6.6	4.2	6.4	23.8
6.	Carpet Finishing	25.6	82.3	4.7	1.1	11.3	3.4	9.4
7.	Stock & Yarn Finishing	20.7	62.7	4.6	1.6	15.0	12.0	27.8
8.	Nonwoven Manufacturing	6.7	38.4	2.2	#	#	0.5	#
9.	Felted Fabric Processing	70.2	186.0	64.1	11.2	247.4	#	#

Insufficient data to report value.

Source: Table B-1, Appendix B.

TABLE V-4
RAW WASTE CONCENTRATIONS - CONVENTIONAL AND NON-CONVENTIONAL POLLUTANTS
RESULTS OF FIELD SAMPLING PROGRAM

Mill Subcategory	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	O & G (mg/l)	Phenol (ug/l)	Chromium (ug/l)	Sulfide (ug/l)	Color APHA Units	pH Units
Wool Scouring	1900	6100	2300	-	-	10	500	2200	10.4
Wool Scouring	5000	24000	87000	1100	-	220	-	-	7.8
Wool Finishing	450	1700	160	-	90	190	6000	2000	10.7
Wool Finishing	330	1100	70	-	160	880	1100	1000	9.2
Low Water Use Processing	-	1900	-	-	80	10	1000	-	-
Low Water Use Processing	-	720	15	80	-	4	ND	10	6.9
Woven Fabric Finishing									
Simple Processing	50	-	55	-	20	4	1000	500	9.0
Simple Processing	400	1100	200	-	90	8	200	-	-
Complex Processing	500	500	30	-	70	-	7600	1300	9.5
Complex Processing	450	1700	90	-	280	70	1000	1500	10.5
Complex Processing	-	2000	-	-	150	15	1000	-	-
Complex Processing	1500	-	500	20	-	35	-	-	11.2
Complex Processing	600	1600	15	-	-	5	-	-	9.3
Complex Plus Desizing	290	320	40	-	-	4	20	1200	10.0
Complex Plus Desizing	20	2700	50	-	70	10	1000	250	10.0
Complex Plus Desizing	400	1500	110	-	55	25	5600	3200	10.0
Complex Plus Desizing	560	1700	70	-	65	20	1000	40,000	10.0
Complex Plus Desizing	440	800	50	-	75	35	5200	2600	11.2
Complex Plus Desizing	350	800	20	-	55	-	2500	500	10.0

Notes: A dash indicates that analyses were not performed.
ND indicates "Not Detected"

TABLE V-4 (Cont.)

Mill Subcategory	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	O&G (mg/l)	Phenol (ug/l)	Chromium (ug/l)	Sulfide (ug/l)	Color APHA Units	pH Units
Knit Fabric Finishing									
Simple Processing	-	-	6	-	230	-	6000	300	10.0
Simple Processing	200	580	25	-	740	6	2100	150	9.2
Simple Processing	240	780	20	320	940	20	750	740	10.2
Complex Processing	220	560	25	-	110	1	9200	250	10.0
Complex Processing	-	730	25	-	1	10	1000	-	-
Hosiery Products	-	880	20	180	-	660	1800	820	7.5
Hosiery Products	-	820	180	340	-	8	ND	220	9.1
Hosiery Products	-	2900	95	630	-	-	ND	270	6.4
Carpet Finishing	200	1300	40	-	30	4	1000	300	11.0
Carpet Finishing	-	940	-	-	45	25	1000	-	-
Carpet Finishing	180	740	20	-	-	55	-	-	-
Stock & Yarn Finishing	1100	1300	30	-	40	10	1400	1400	10.5
Stock & Yarn Finishing	380	1100	20	-	40	3	4500	1300	7.4
Stock & Yarn Finishing	120	460	35	-	65	25	1000	10,000	10.5
Stock & Yarn Finishing	-	-	-	-	-	650	-	-	-
Stock & Yarn Finishing	-	640	125	210	-	-	ND	310	6.2
Nonwoven Manufacturing	-	340	-	-	45	10	1000	-	-
Nonwoven Manufacturing	-	220	35	-	-	4	ND	140	9.4
Nonwoven Manufacturing	-	480	15	-	-	-	ND	35	6.3
Felted Fabric Processing	-	1100	40	-	-	-	1200	190	7.3

Notes: A dash indicates that analyses were not performed .
ND indicates "Not Detected".

TABLE V-5
TYPICAL RAW WASTE CONCENTRATIONS - CONVENTIONAL AND NON-CONVENTIONAL POLLUTANTS
SUMMARY OF HISTORICAL AND FIELD SAMPLING DATA

	Subcategory	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	O&G (mg/l)	Phenol (ug/l)	Chromium (ug/l)	Sulfide (ug/l)	Color APHA Units
1.	Wool Scouring	2300	7000	3300	600	#	(120)	(500)	(2200)
2.	Wool Finishing	170	600	60	#	(120)	(500)	(3500)	(1500)
3.	Low Water Use Processing	290	690	180	(80)	#	(4)	#	(10)
4.	Woven Fabric Finishing								
	a. Simple Processing	270	900	60	70	50	40	70	800
	b. Complex Processing	350	1100	110	50	50	110	110	(1400)
	c. Complex Processing Plus Desizing	420	1240	150	70	150	100	(1700)	(1900)
5.	Knit Fabric Finishing								
	a. Simple Processing	210	870	50	80	110	80	50	400
	b. Complex Processing	270	790	60	50	100	80	150	750
	c. Hosiery Products	320	1370	80	100	60	80	560	450
6.	Carpet Finishing	440	1190	70	20	130	30	175	490
7.	Stock & Yarn Finishing	180	680	40	20	170	100	200	570
8.	Nonwoven Manufacturing	180	2360	80	(60)	(40)	(10)	#	(90)
9.	Felted Fabric Processing	200	550	120	30	(580)	#	(1200)	(200)

Insufficient data to report value.
( ) Value is median of field sampling results.

Processing Plus Desizing Woven Fabric Finishing, 13 Simple Processing Knit Fabric Finishing, 5 Complex Processing Knit Fabric Finishing, 2 Hosiery Products Knit Fabric Finishing, 6 Carpet Finishing, and 13 Stock & Yarn Finishing. In order to qualify as BPT, the treatment chain had to include extended-aeration (at least 24-hours detention) activated sludge followed by secondary sedimentation with sludge return to the aeration basin. In addition to the wetprocessing subcategories data, treated effluent data are available for 17 Low Water Use Processing mills. The treatment at these mills is biological, but is not necessarily BPT. The data are included here in characterizing BPT effluents. Additional information about current industry treatment practices is provided in Section VII.

Statistical summaries of the reported historical BPT effluent concentrations and mass loading values for the conventional and non-conventional pollutant parameters are presented as Table B-2 in Appendix B. The formats of the summaries are similar to those used for the raw waste summaries discussed above. While there are much less BPT data available, they are more consistent than the raw waste data and median values are often similar in magnitude to the average values. This is logical because effective BPT treatment systems should produce effluents with similar characteristics.

BPT effluent concentrations for the conventional and non-conventional pollutant parameters for each subcategory are presented in Table V-6. The values are medians of reported values rounded off for clearer presentation. Values are reported for each parameter for which data were available. Reporting all data in contrast to reporting values for which three or more mills are represented (as with raw waste values) is believed to be justified because BPT normally provides more consistent results regardless of the characteristics of the influent raw waste. Based on the values reported, the treatment provided to the wastes from the Wool Scouring, Wool Finishing, and Knit Fabric Finishing-Hosiery Products subcategories appears to be less effective than for the other subcategories.

For Subcategory 1, Wool Scouring, the data are from only two mills. In wool scouring wastewaters it is generally recognized that emulsified wool grease is responsible for the higher conventional pollutant concentrations. The relatively large COD value compared to BOD indicates that wool grease is not readily biodegradable. The values for oil & grease, phenol, chromium, sulfide, and color are from a single mill and, as such, may not be representative.

The data for the Wool Finishing subcategory are also reflective of only two mills. Although a median oil & grease value is not available from the historical data, it is known that oils present in wool yarn after spinning must be removed by finishing mills in the heavy scour step to ensure satisfactory dyeing. Removal of this grease increases

TABLE V-6
BPT EFFLUENT CONCENTRATIONS - CONVENTIONAL AND NON-CONVENTIONAL POLLUTANTS
HISTORICAL DATA - MEDIAN VALUES

Subcategory	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	O&G (mg/l)	Phenol (ug/l)	Chromium (ug/l)	Sulfide (ug/l)	Color APHA Units
1. Wool Scouring	92	2000	700	190	100	37	360	1900
2. Wool Finishing	50	530	95	#	81	200	#	#
3. Low Water Use Processing	24	223	28	#	64	60	90	#
4. Woven Fabric Finishing								
a. Simple Processing	15	240	38	24	20	20	130	340
b. Complex Processing	24	250	48	#	110	25	60	#
c. Complex Processing Plus Desizing	24	250	49	9	34	29	1120	120
5. Knit Fabric Finishing								
a. Simple Processing	13	270	34	14	56	58	130	190
b. Complex Processing	21	280	55	32	65	25	55	#
c. Hosiery Products	71	570	130	#	34	30	56	#
6. Carpet Finishing	34	290	63	6	100	25	63	310
7. Stock & Yarn Finishing	11	140	25	#	56	42	120	470
8. Nonwoven Manufacturing	#	#	#	#	#	#	#	#
9. Felted Fabric Processing	#	#	#	#	#	#	#	#

No data

Source: Table B-2, Appendix B.

the organic load and causes the non-biodegradable organic content to be relatively high. The value for phenol represents data from only one mill, and the chromium value represents data from two mills, both of which employ chromium-based dyes for part of their production. Historical data were not available for sulfide and color.

The values for the Knit Fabric Finishing-Hosiery Products subcategory are also based on limited data because most of these mills are indirect dischargers. The two mills represented have marginal BPT treatment components and the data may not be as representative of BPT as data for other subcategories.

The values for the conventional pollutant parameters for the other subcategories, with the exception of Nonwoven Manufacturing and Felted Fabric Processing, are generally supported by adequate data. The non-conventional parameters are represented by fewer data points, but are reasonably consistent.

Waste mass loading values for BPT effluents are reported in Table V-7. They represent median values for each parameter for which data are available. Although based on only two data points each, Wool Finishing and Wool Scouring mills appear to be discharging greater quantities of pollutants. This is logical since their raw waste loads are also high.

The median BPT effluent waste loads for the Woven and Knit Fabric Finishing subcategories are generally equivalent; however, the chemical constituents responsible for the waste characteristics are different (see "Discussion of Raw Wastewater Characteristics" at beginning of Section V) so the treatability of these wastes do not share the same similarity. The only outstanding difference in the characteristics is the sulfide value for the Woven Fabric Finishing-Complex Processing Plus Desizing subcategory.
A close inspection of this value reveals that, of the four mills for which data are available, three use sulfur dyes on a significant portion of their production. Since the dyes contain sulfur linkages within their molecules and sodium sulfide is used as a reducing agent in sulfur dyeing, sulfur could be expected to show up in the effluent.

The conventional and non-conventional pollutant data collected in conjunction with the field sampling program provide some additional characterization of BPT effluents that serve both to confirm and to fill gaps in the historical data base. The data for each mill sampled are presented in Table V-8. These data represent samples collected using the same procedures explained above for raw wastewaters.

Typical BPT effluent waste concentrations for the conventional and non-conventional pollutants, based on the historical data and the field sampling results, are presented in Table V-9. These data are

TABLE V-7
BPT EFFLUENT LOADS - CONVENTIONAL AND NON-CONVENTIONAL POLLUTANTS
HISTORICAL DATA - MEDIAN VALUES

Subcategory	BOD (kg/kkg)	COD (kg/kkg)	TSS (kg/kkg)	O&G (kg/kkg)	Phenol (g/kkg)	Chromium (g/kkg)	Sulfide (g/kkg)
1. Wool Scouring	4.0	82.0	37.8	11.2	6.2	2.2	20.7
2. Wool Finishing	25.1	273.1	46.4	#	#	94.3	#
3. Low Water Use Processing	0.1	2.7	0.2	#	0.6	#	0.7
4. Woven Fabric Finishing							
a. Simple Processing	2.6	33.6	4.8	5.2	2.8	2.6	16.6
b. Complex Processing	4.0	39.0	7.6	#	17.4	3.7	9.6
c. Complex Processing Plus Desizing	2.1	29.4	4.6	1.0	3.0	2.4	92.3
5. Knit Fabric Finishing							
a. Simple Processing	1.6	28.6	3.5	1.1	7.8	5.7	20.8
b. Complex Processing	3.2	40.4	5.9	5.9	10.7	1.9	9.9
c. Hosiery Products	4.0	23.7	5.4	#	1.4	1.2	2.3
6. Carpet Finishing	1.6	15.3	3.1	0.7	4.8	1.4	5.2
7. Stock & Yarn Finishing	0.8	11.4	2.1	#	6.6	3.9	12.1
8. Nonwoven Manufacturing	#	#	#	#	#	#	#
9. Felted Fabric Processing	#	#	#	#	#	#	#

No data

Source: Table B-2, Appendix B.

TABLE V-8
BPT EFFLUENT CONCENTRATIONS - CONVENTIONAL AND NON-CONVENTIONAL POLLUTANTS
RESULTS OF FIELD SAMPLING PROGRAM

Mill Subcategory	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	O & G (mg/l)	Phenol (ug/l)	Chromium (ug/l)	Sulfide (ug/l)	Color APHA Units	pH Units
Wool Scouring	84	840	300	-	-	3	10	1900	8.1
Wool Scouring	140	1300	76	5.0	-	17	-	-	8.4
Wool Finishing	170	1650	230	-	65	150	4000	2000	7.3
Wool Finishing	36	290	77	-	68	1800	100	90	7.0
Woven Fabric Finishing									
Simple Processing	5	130	26	-	16	3	1000	500	7.1
Simple Processing	67	590	27	-	24	5	-	-	7.1
Complex Processing	70	830	220	-	140	160	1000	2000	8.1
Complex Processing	-	450	-	-	13	52	1000	-	-
Complex Processing	16	-	36	8.0	5	-	-	-	8.0
Complex Processing	40	-	20	-	5	-	-	-	8.0
Complex Plus Desizing	14	300	43	-	-	-	20	500	7.6
Complex Plus Desizing	5	78	19	-	14	4	1000	30	7.2
Complex Plus Desizing	24	750	92	-	7	14	3500	2480	7.3
Complex Plus Desizing	5	130	21	-	18	4	1000	150	7.2
Complex Plus Desizing	5	260	21	-	25	-	1000	500	7.5
Complex Plus Desizing	25	400	300	-	88	31	5000	1920	10.0
Complex Plus Desizing	5	110	13	-	23	-	1000	750	8.0

Note: A dash indicates that analysis was not performed.

TABLE V-8 (Cont.)

Mill Subcategory	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	O & G (mg/l)	Phenol (ug/l)	Chromium (ug/l)	Sulfide (ug/l)	Color APHA Units	pH Units
Knit Fabric Finishing									
Simple Processing	28	45	45	-	32	-	6000	250	7.1
Simple Processing	-	320	42	270	32	36	ND	190	7.0
Complex Processing	59	1000	580	-	29	-	1000	75	7.8
Complex Processing	-	160	-	-	94	20	1000	-	-
Carpet Finishing	42	500	6	-	54	-	1000	300	7.5
Carpet Finishing	-	240	-	-	14	170	1000	-	-
Carpet Finishing	40	250	28	-	-	360	-	-	-
Stock & Yarn Finishing	5	99	8	-	4	15	200	90	7.5
Stock & Yarn Finishing	13	230	78	-	26	30	3000	370	5.8
Stock & Yarn Finishing	5	120	17	-	22	-	1000	250	8.0
Stock & Yarn Finishing	-	78	37	92	-	6	2000	210	6.4
Felted Fabric Processing	-	550	91	190	-	35	ND	280	7.2

Note: A dash indicates that analysis was not performed.
ND indicates "Not Detected".

TABLE V-9
TYPICAL BPT EFFLUENT CONCENTRATIONS - CONVENTIONAL AND NON-CONVENTIONAL POLLUTANTS
SUMMARY OF HISTORICAL AND FIELD SAMPLING DATA

Subcategory	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	O&G (mg/l)	Phenol (ug/l)	Chromium (ug/l)	Sulfide (ug/l)	Color APHA Units
1. Wool Scouring	90	2000	700	190	100	40	360	1900
2. Wool Finishing	50	530	100	#	80	200	(2000)	(1000)
3. Low Water Use Processing	25	220	30	#	60	60	90	#
4. Woven Fabric Finishing								
a. Simple Processing	15	240	40	25	20	20	130	340
b. Complex Processing	25	250	50	(8)	110	30	60	(2000)
c. Complex Processing Plus Desizing	25	250	50	9	35	30	1100	120
5. Knit Fabric Finishing								
a. Simple Processing	15	270	35	15	55	60	130	190
b. Complex Processing	20	280	55	30	65	25	55	75
c. Hosiery Products	70	570	130	#	35	30	55	#
6. Carpet Finishing	35	290	60	#	100	25	60	310
7. Stock & Yarn Finishing	10	140	25	(90)	55	40	120	470
8. Nonwoven Manufacturing	#	#	#	#	#	#	#	#
9. Felted Fabric Processing	#	#	#	#	#	#	#	#

\# Insufficient data to establish a typical value.
( ) Value is median of field sampling results.

the best available for mills with BPT treatment. While some additional data were collected for mills that have other than BPT treatment, they are not of direct significance here. These mills and the data are discussed in Section VII.

The BPT effluent values are in general believed to be representative of typical effluents from each subcategory and are those used in developing the treatment technologies and costs in subsequent sections. There are several subcategory-parameter combinations for which a typical value could not be presented, and two subcategories, Nonwoven Manufacturing and Felted Fabric Processing, are predominantly indirect dischargers and no useful data are available.

TOXIC POLLUTANTS

The Clean Water Act of 1977 expanded the spectrum of pollutant parameters to receive attention in point source discharges to include potentially toxic pollutants. More specifically, 65 classes of toxic compounds and groups originally identified in the Consent Decree in NRDC vs Train, 8 ERC 2120 (D.D.C 1976) have been made subject to effluent limitations.

The 65 classes were selected as the most important of 232 pollutant categories considered to be of the greatest environmental concern. The selections were based on the following criteria:

- o "Substances for which there is substantial evidence of carcinogenicity, mutagenicity and/or teratogenicity;
- o Substances structurally similar to the aforementioned compounds or for which there is some evidence of carcinogenicity, mutagenicity, or teratogenicity; and
- o Substances known to have toxic effects on man or aquatic organisms at sufficiently high concentrations and which are present in industrial effluents."

Within the 65 classes, 129 specific elements or compounds have been identified as toxic pollutants. These include 13 metals, 114 organic compounds, cyanides, and asbestos. A list of all 129 pollutants is provided in Appendix C.

Heavy Metals

The 13 toxic pollutant metals, which include the traditional heavy metals, are:

antimony
arsenic

beryllium
cadmium
chromium
copper
lead
mercury
nickel
selenium
silver
thallium
zinc

The heavy metals are often thought of as a group because of their several common characteristics and behavioral properties, but each has distinctive characteristics that influence its behavior and the effect that it will have on the environment. In addition to the individual characteristics of a metal acting alone, synergistic or antagonistic effects have been observed between metals in terms of toxicity and the capacity to remove them from a waste stream. Generally, the insoluble compounds and complexes tend to be more prevalent than the dissolved forms, but metals can exist in solution and in various complexes with organic materials.

The concentrations of metals in many waste streams are higher than the concentrations of individual toxic organics. Metals are not appreciably biodegradable and removal mechanisms depend upon physicochemical processes. While there is still much to be learned about the behavior of metals and their impact on removal systems, there has been a considerable amount of research in this area in recent years.

<u>Organics</u>

The 114 organic compounds can be subdivided into the following broad classifications:

Aliphatics	36
Aromatics	59
Pesticides	19

Approximately 30 of the compounds can be considered volatile, and 69 contain chlorine. Compared to the metals, the majority of the toxic organic compounds are usually present at much lower concentrations, some in only fractions of micrograms per liter (ug/l). These concentrations are relatively insignificant compared to the organics that are measured by the standard BOD, COD, or TOC tests. The organics provide a much greater variety of molecular structures and behavioral patterns in wastewater than do the metals, however.

Much of the focus of this study as well as the information presented below and in Section VI revolves about the 129 representative toxic pollutants.

Questionnaire Information

Most of the organic toxic pollutants are specific compounds and more sophisticated laboratory analytical techniques are required than for the non-specific parameters such as solids, COD, alkalinity, etc. Also, as noted above, the concentrations of interest are considerably lower than for most of the conventional and non-conventional pollutants, and more elaborate sample collection and handling methods are necessary to insure that meaningful and reproducible results are obtained. Because of these aspects, there is relatively little historical information about the presence or concentrations of most of the toxic pollutants, especially the non-metals, in textile mill wastewaters.

One source of information utilized in developing information about the toxic pollutants in textile wastes was the questionnaires received from wet processing mills. The questionnaire survey has been described previously, and a sample of the questionnaire is provided in the Appendix. Section VI of the questionnaire asked that the mills identify whether each of the 123 toxic pollutants[1] was known present, suspected present, suspected absent, or known absent, in the raw wastewater or treated effluent. The responses for each pollutant were tallied for the mills that provided what was judged to be a good reply to Section VI. A summary of the responses for all mills is presented in Table V-10. The summary represents the responses from 418 mills and shows that 52 pollutants are known to be present and an additional 47 are suspected to be present by at least one mill. A total of 69 pollutants are reported known or suspected present by more than two mills; only 29 of these are known to be present by more than two mills.

Field Sampling Program

Because of the non-existence of historical data on the toxic pollutants noted above, it was necessary to perform a comprehensive field sampling program. The program was organized to involve four phases. The first phase was conducted in connection with the joint

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[1]At the time of the survey distribution (March, 1977), the toxic pollutant list contained only 123 compounds; shortly thereafter, the list was increased to 129 with the addition of di-n-octyl phthalate, PCB-1221, PCB-1232, PCB-1248, PCB-1260, and PCB-1016

TABLE V-10
INDUSTRY RESPONSES TO PRIORITY POLLUTANTS LIST
SUMMARY OF ALL MILLS

Priority Pollutant	Known Present	Suspected Present	Known Absent	Suspected Absent
1. acenaphthene		7	262	43
2. acrolein		3	264	46
3. acrylonitrile	6	26	243	38
4. benzene	5	27	254	40
5. benzidine	6	42	236	43
6. carbon tetrachloride (tetrachloromethane)	1	9	244	61
7. chlorobenzene	4	28	235	44
8. 1,2,4-trichlorobenzene	33	53	182	38
9. hexachlorobenzene	1	5	256	48
10. 1,2-dichloroethane	1	6	245	50
11. 1,1,1-trichloroethane	5	34	233	46
12. hexachloroethane		1	260	51
13. 1,1-dichloroethane	1	1	258	53
14. 1,1,2-trichloroethane		9	254	52
15. 1,1,2,2-tetrachloroethane		2	258	52
16. chloroethane	1	8	256	48
17. bis(chloromethyl) ether		5	246	60
18. bis(2-chloroethyl) ether		3	255	53
19. 2-chloroethyl vinyl ether (mixed)		1	256	54
20. 2-chloronaphthalene	3	2	263	42
21. 2,4,6-trichlorophenol		7	260	44
22. parachlorometa cresol		3	259	47
23. chloroform (trichloromethane)	2	5	249	55
24. 2-chlorophenol	1	8	257	43
25. 1,2-dichlorobenzene	2	16	252	40
26. 1,3-dichlorobenzene	2	9	259	40
27. 1,4-dichlorobenzene	2	8	259	40
28. 3,3-dichlorobenzidine	1	10	260	41
29. 1,1-dichloroethylene			267	41
30. 1,2-trans-dichloroethylene		2	265	41
31. 2,4-dichlorophenol		2	263	43
32. 1,2-dichloropropane			263	45
33. 1,3-dichloropropylene			263	45
34. 2,4-dimethylphenol		2	260	45
35. 2,4-dinitrotoluene		3	261	45
36. 2,6-dinitrotoluene		3	262	44
37. 1,2-diphenylhydrazine		5	263	39
38. ethylbenzene	2	7	256	41
39. fluoranthene		1	263	42
40. 4-chlorophenyl phenyl ether		4	264	41

TABLE V-10 (Cont.)

Priority Pollutant	Known Present	Suspected Present	Known Absent	Suspected Absent
41. 4-bromophenyl phenyl ether		1	266	43
42. bis(2-chloroisopropyl) ether		1	263	46
43. bis(2-chloroethoxy) methane			265	45
44. methylene chloride (dichloromethane)	3	17	242	41
45. methyl chloride (chloromethane)	1	2	264	43
46. methyl bromide (bromomethane)		4	265	43
47. bromoform (tribromomethane)		1	266	44
48. dichlorobromomethane			265	46
49. trichlorofluoromethane			264	45
50. dichlorodifluoromethane			263	45
51. chlorodibromomethane			261	49
52. hexachlorobutadiene		5	260	44
53. hexachlorocyclopentadiene		2	265	43
54. isophorone		1	262	45
55. naphthalene	7	48	232	33
56. nitrobenzene		7	260	42
57. 2-nitrophenol		2	262	43
58. 4-nitrophenol		2	260	43
59. 2,4-dinitrophenol		4	257	43
60. 4,6-dinitro-o-cresol		2	259	45
61. N-nitrosodimethylamine		5	260	42
62. N-nitrosodiphenylamine		4	261	42
63. N-nitrosodi-n-propylamine			265	42
64. pentachlorophenol	2	15	248	45
65. phenol (4APP)	81	48	161	38
66. bis(2-ethylhexyl) phthalate		4	263	41
67. butyl benzyl phthalate	3	2	261	43
68. di-n-butyl phthalate	1	6	261	42
69. di-n-octyl phthalate*				
70. diethyl phthalate		7	261	41
71. dimethyl phthalate	8	17	243	40
72. 1,2 benzanthracene		5	260	41
73. 3,4-benzopyrene		2	261	43
74. 3,4-benzofluoranthene		1	263	44
75. 11,12-benzofluoranthene		1	262	45
76. chrysene		1	262	44
77. acenaphthylene	3	2	262	41
78. anthracene	2	8	256	41
79. 1,12-benzoperylene		2	259	45
80. fluorene	1	4	256	45

TABLE V-10 (Cont.)

Priority Pollutant	Known Present	Suspected Present	Known Absent	Suspected Absent
81. phenanthrene		3	260	43
82. 1,2,5,6-dibenzanthracene		6	258	42
83. indeno(1,2,3-cd) pyrene			261	46
84. pyrene		2	261	45
85. tetrachloroethylene	10	19	242	43
86. toluene	8	40	223	43
87. trichloroethylene	4	17	251	40
88. vinyl chloride (chloroethylene)		5	253	47
89. aldrin	2	1	242	78
90. dieldrin	1		241	78
91. chlordane (technical mixture and metabolites)	1		242	78
92. 4,4'-DDT		1	239	82
93. 4,4'-DDE (p,p'-DDX)			240	82
94. 4,4'-DDD (p,p'-TDE)			240	82
95. alpha-endosulfan			243	77
96. beta-endosulfan			243	77
97. endosulfan sulfate			244	77
98. endrin			246	77
99. endrin aldehyde			246	77
100. heptachlor	1	1	246	77
101. heptachlor epoxide			246	77
102. alpha-BHC			244	77
103. beta-BHC			245	77
104. gamma-BHC (lindane)	1		245	77
105. delta-BHC			245	77
106. PCB-1242 (Arochlor 1242)			244	79
107. PCB-1254 (Arochlor 1254)			244	79
108. PCB-1221 (Arochlor 1221)*				
109. PCB-1232 (Arochlor 1232)*				
110. PCB-1248 (Arochlor 1248)*				
111. PCB-1260 (Arochlor 1260)*				
112. PCB-1016 (Arochlor 1016)*				
113. Toxaphene		1	243	77
114. Antimony (Total)	16	36	208	56
115. Arsenic (Total)	10	6	246	70
116. Asbestos (Fibrous)	3	3	257	65
117. Beryllium (Total)	2	5	257	65
118. Cadmium (Total)	24	17	219	57
119. Chromium (Total)	117	55	117	38
120. Copper (Total)	87	79	146	27

TABLE V-10 (Cont.)

Priority Pollutant	Known Present	Suspected Present	Known Absent	Suspected Absent
121. Cyanide (Total)	10	6	240	72
122. Lead (Total)	34	27	204	59
123. Mercury (Total)	19	15	212	68
124. Nickel (Total)	28	28	208	53
125. Selenium (Total)	7	3	242	59
126. Silver (Total)	12	4	244	56
127. Thallium (Total)	2	1	251	59
128. Zinc (Total)	100	64	140	30
129. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)		1	260	44

* Pollutant not included on original list of 123.

Known Present - The compound has been detected by reasonable analytical procedures in the discharge or by reference is known to be present in the raw waste load.

Suspected Present- The compound is a raw material in the processes employed, a product, a by-product, catalyst, etc. Its presence in the raw waste load and discharge is a reasonable technical judgment.

Suspected Absent - No known reason to predict that the compound is present in the discharge.

Known Absent - The application of reasonable analytical procedures designed to detect the material have yielded negative results.

ATMI/EPA mobile pilot plant project. Raw waste, secondary effluent, and, in some cases, advanced treatment effluent samples were collected at 23 locations during March, April, and May of 1977. In the second phase, raw waste and secondary effluent samples were collected at 8 additional locations and from the various advanced treatment modes of the mobile pilot plant at 1 previously sampled location during May, June, and July of 1977. Water supply, raw waste, secondary effluent, and/or advanced treatment effluent samples were collected during the third phase at 13 additional locations and from the various advanced treatment modes of the mobile pilot plant at 1 previously sampled location during September, October, and November of 1977. An additional 10 locations were sampled in the fourth phase to investigate the day-to-day fluctuations in raw wastes and treated effluents. This phase also studied the efficiency of various full scale advanced, physicochemical treatment technologies. Six additional mills and nine previously sampled mills were sampled in May through October 1978.

The scope of the field sampling program, to date, is presented in Table V-11. A total of 50 mills was sampled, including all nine subcategories, with more emphasis placed on the major subcategories in terms of number and size of establishments. Most of the direct discharge mills provide BPT (secondary) treatment, and a few provide additional (advanced) treatment processes. The sample collection and handling procedures employed by each sampling crew and the laboratory analytical procedures used conformed to protocols developed by EPA. A summary of the procedures is provided in Appendix D.

The overall qualitative results of the field sampling program of raw textile mill wastewaters by subcategory are presented in Table V-12. All positive results are included whether or not the concentration is regarded as meaningful in terms of analytical accuracy or environmental impact. Three of the toxic pollutants (Bis 2-ethylhexyl) phthalate, copper, and zinc were detected in all nine major subcategories. An additional five pollutants were detected in eight of the nine major subcategories. At the opposite end of the scale, 18 toxic pollutants were detected in only a single subcategory. This reflects the wide variety of manufacturing methods and process machinery in the textile industry and, perhaps, the fluctuating character of textile wastes caused by batch operations and frequent changes in product line. Of interest was the finding that the average number of organic toxic pollutants detected at 44 mills was approximately six. The quantitative results of the field sampling program are summarized in Table V-13, with the median and maximum concentrations and the numbers of mills where detected. Results are shown for the water supply, the raw wastes, and the secondary treatment effluent. The results from advanced treatment units are included in Section VII to describe the performance of the different technologies. It should be noted (Table V-11) that water supply

TABLE V-11
SUMMARY OF MILL CHARACTERISTICS AND SAMPLE COLLECTION
FIELD SAMPLING PROGRAM

	Mill Type	Typical Processing	Products	Samples Collected: Water Supply	Samples Collected: Raw Waste	Samples Collected: Secondary	Samples Collected: Advanced
1.	Wool Scouring	Raw wool scouring	Wool top		X	X	
1.	Wool Scouring	Raw wool scouring, heavy scour, carbonizing, bleaching	Wool top & wool/ polyester fabric		X	X	
1.	Wool Scouring	Raw wool scouring, spinning	Wool top & carpet yarn		X	X	
2.	Wool Finishing	Heavy scouring, stock & yarn dyeing	Woven fabric		X	X	
2.	Wool Finishing	Heavy scouring, bleaching, stock & yarn dyeing	Apparel & upholstery fabric		X	X	
3.	Low Water Use Processing	Spinning, slashing, weaving	Woven greige goods		X		
3.	Low Water Use Processing	Water-jet weaving	Woven greige goods	X	X		

TABLE V-11 (Cont.)

Mill Type	Typical Processing	Products	Samples Collected Water Supply	 Raw Water	 Secondary	 Advanced
4. Woven Fabric Finishing						
a. Simple Processing	Piece dyeing	Upholstery fabric		X	X	
a. Simple Processing	Printing	Sheets, blankets, towels		X	X	X
b. Complex Processing	Scouring, bleaching, printing, piece dyeing	Finished fabric		X	X	
b. Complex Processing	Desizing, scouring, bleaching, mercerizing, printing, dyeing	Finished fabric		X	X	
b. Complex Processing	Slashing, weaving, desizing, bleaching, printing, dyeing	Sheets & towels		X	X	
c. Complex Processing Plus Desizing	Desizing, scouring, bleaching, mercerizing, piece dyeing	Finished fabric		X	X	
c. Complex Processing Plus Desizing	Weaving, desizing, scouring, bleaching, printing, piece dyeing	Sheets		X	X	

TABLE V-11 (Cont.)

Mill Type	Typical Processing	Products	Samples Collected			
			Water Supply	Raw Water	Secon-dary	Ad-vanced
c. Complex Processing Plus Desizing	Desizing, scouring, bleaching, piece dyeing	Finished fabric		X	X	
c. Complex Processing Plus Desizing	Desizing, scouring, bleaching, mercerizing, dyeing	Finished fabric	X	X	X	X*
c. Complex Processing Plus Desizing	Desizing, scouring, bleaching, mercerizing, piece dyeing	Sheeting & shirting		X	X	
c. Complex Processing Plus Desizing	Desizing, scouring, bleaching, mercerizing, piece dyeing	Finished fabric		X	X	
c. Complex Processing Plus Desizing	Desizing, scouring, bleaching, mercerizing, piece dyeing	Finished fabric		X	X	
c. Complex Processing Plus Desizing (Commission Finisher)	Desizing, scouring, bleaching, mercerizing, yarn & piece dyeing	Finished fabric		X	X	

* Collected from mobile pilot plant.

TABLE V-11 (Cont.)

Mill Type	Typical Processing	Products	Samples Collected Water Supply	Raw Water	Secondary	Advanced
c. Complex Processing Plus Desizing	Desizing, scouring, bleaching, mercerizing, printing, piece dyeing	Sheeting		X	X	
c. Complex Processing Plus Desizing	Desizing, scouring, mercerizing, printing, piece dyeing	Sheeting & apparel	X	X	X	
c. Complex Processing Plus Desizing	Slashing, weaving, desizing, scouring, bleaching, yarn dyeing	Denim fabric	X	X	X	
5. Knit Fabric Finishing						
a. Simple Processing	Scouring, piece dyeing	Apparel fabric		X	X	
a. Simple Processing	Piece dyeing	Outerwear fabric		X	X	
a. Simple Processing	Piece dyeing	Apparel & auto upholstery fabric	X	X	X	X*
b. Complex Processing	Scouring, bleaching, printing, piece dyeing	Apparel fabric		X	X	

* Collected from in-place technology and mobile pilot plant.

TABLE V-11 (Cont.)

Mill Type	Typical Processing	Products	Samples Collected: Water Supply	Raw Water	Secondary	Advanced
b. Complex Processing	Scouring, bleaching, piece dyeing	Finished fabric		X	X	
c. Hosiery Products	Piece dyeing	Men's hosiery	X	X	X	
c. Hosiery Products	Scouring, bleaching, piece dyeing	Men's hosiery	X	X	X*	
c. Hosiery Products	Piece dyeing	Ladies' hosiery	X	X		
6. Carpet Finishing	Tufting, piece dyeing, latex backing	Finished carpet		X	X	
6. Carpet Finishing	Tufting, piece dyeing, latex backing	Finished carpet		X	X	
6. Carpet Finishing	Tufting, printing, piece dyeing, latex backing	Finished carpet	X	X	X	
7. Stock & Yarn Finishing	Desizing, scouring, bleaching	Surgical gauze & cotton		X	X	
7. Stock & Yarn Finishing	Yarn dyeing	Greige & finished yarn		X	X	
7. Stock & Yarn Finishing	Bleaching, mercerizing, yarn dyeing	Sewing thread & yarn		X	X	

* Effluent from holding basin.

TABLE V-11 (Cont.)

	Mill Type	Typical Processing	Products	Samples Collected			
				Water Supply	Raw Water	Secon-dary	Ad-vanced
7.	Stock & Yarn Finishing	Yarn dyeing	Finished yarn		X	X	
7.	Stock & Yarn Finishing	Yarn dyeing	Finished yarn		X	X	
7.	Stock & Yarn Finishing	Wool scouring, stock dyeing, yarn dyeing	Carpet yarn	X	X	X	X*
8.	Nonwoven Manufacturing	Carding, adhesive bonding	Disposable wiping towels		X		
8.	Nonwoven Manufacturing	Carding, adhesive bonding, viscose regeneration	Finished fabric	X	X		
8.	Nonwoven Manufacturing	Fiber preparation, wet lay, adhesive bonding	Finished fabric	X	X		
9.	Felted Fabric Processing	Weaving, scouring, felting	Papermaker's felt	X	X	X	X*

* Collected from polishing pond.

TABLE V-12
TOXIC POLLUTANTS DETECTED IN TEXTILE MILL RAW WASTEWATERS

Pollutant	Subcategory 1	2	3	4a	4b	4c	5a	5b	5c	6	7	8	9
1. acenaphthene				X			X			X			
3. acrylonitrile									X				
4. benzene	X			X	X	X			X	X		X	
7. chlorobenzene	X				X		X			X			
8. 1,2,4-trichlorobenzene	X			X		X	X	X					
9. hexachlorobenzene	X			X									
10. 1,2-dichloroethane				X									
11. 1,1,1-trichloroethane	X			X			X						
13. 1,1-dichloroethane	X												
20. 2-chloronaphthalene										X			
21. 2,4,6-trichlorophenol					X	X			X	X			
22. parachlorometacresol						X							
23. chloroform	X		X	X	X	X	X	X	X	X	X	X	
24. 2-chlorophenol					X								
25. 1,2-dichlorobenzene	X	X				X	X	X			X		
27. 1,4-dichlorobenzene		X					X						
29. 1,1-dichloroethylene	X												
31. 2,4-dichlorophenol						X				X			
32. 1,2-dichloropropane						X							
36. 2,6-dinitrotoluene											X		
37. 1,2-diphenylhydrazine										X			
38. ethylbenzene	X	X		X	X	X	X	X		X	X	X	
44. methylene chloride				X		X				X			
45. methyl chloride										X			
48. dichlorobromomethane										X			

TABLE V-12 (Cont.)

Toxic Pollutant	Subcategory 1	2	3	4a	4b	4c	5a	5b	5c	6	7	8	9
55. naphthalene		X		X		X	X	X	X	X	X	X	
62. N-nitrosodiphenylamine					X	X			X				
64. pentachlorophenol		X		X	X	X	X					X	
65. phenol (4APP)	X	X	X	X	X	X	X	X	X	X	X		X
66. bis (2-ethylhexyl) phthalate	X	X	X	X	X	X	X		X	X	X	X	X
67. butyl benzyl phthalate												X	
68. di-n-butyl phthalate	X		X	X	X	X	X						
70. diethyl phthalate	X	X			X	X	X				X		
71. dimethyl phthalate				X	X		X				X		
74. 3,4-benzofluoranthene										X			
75. 11,12-benzofluoranthene										X			
78. anthracene										X			
80. fluorene							X						
84. pyrene				X									
85. tetrachloroethylene	X			X				X	X			X	
86. toluene	X			X				X	X				X
87. tricholroethylene	X	X		X	X	X	X		X	X	X	X	X
88. vinyl chloride												X	
114. antimony	X	X	X			X	X	X	X	X	X		
115. arsenic	X				X	X		X	X	X	X		
117. beryllium	X			X		X				X			
118. cadmium	X	X	X	X	X	X	X	X		X	X	X	
119. chromium	X	X	X	X	X	X	X	X	X	X	X	X	
120. copper	X	X	X	X	X	X	X	X	X	X	X	X	X
121. cyanide	X		X	X		X	X		X	X		X	
122. lead	X		X	X	X	X	X	X		X	X		

TABLE V-12 (Cont.)

Toxic Pollutant	Subcategory 1	2	3	4a	4b	4c	5a	5b	5c	6	7	8	9
123. mercury	X	X		X	X	X				X	X		
124. nickel	X	X	X	X	X	X	X	X		X	X	X	
125. selenium			X	X		X	X		X	X	X		X
126. silver	X		X	X	X	X	X	X	X	X	X	X	
127. thallium	X			X		X				X			
128. zinc	X	X	X	X	X	X	X	X	X	X	X	X	X

TABLE V-13

SUMMARY OF ANALYTICAL RESULTS - TOXIC POLLUTANT SAMPLING PROGRAM

Toxic Pollutant	Concentration Observed, micrograms/liter								
	Water Supply			Raw Wastewater			Secondary Effluent		
	Med.	Max.	No.	Med.	Max.	No.	Med.	Max.	No.
1. acenaphthene			*	8.7	12	3		0.5	1
2. acrolein			*			*			*
3. acrylonitrile			*		1600	1		400	1
4. benzene	(4)	(5)	2	(5)	200	10	(5)	64	4
5. benzidine			*			*			*
6. carbon tetrachloride			*			*			*
7. chlorobenzene			*	25	296	5		3.5	1
8. 1,2,4-trichlorobenzene			*	410	2700	8	608	1582	4
9. hexachlorobenzene			*	1.3	2	2			*
10. 1,2-dichloroethane			*		(5)	1			*
11. 1,1,1-trichloroethane		(5)	1	7.8	17	4		(5)	1
12. hexachloroethane			*			*			*
13. 1,1-dichloroethane			*	13	14	1			*
14. 1,1,2-trichloroethane			*			*			*
15. 1,1,2,2-tetrachloroethane			*			*			*
16. chloroethane			*			*			*
17. bis (chloromethyl) ether			*			*			*
18. bis (2-chloroethyl) ether			*			*			*
19. 2-chloroethyl vinyl ether (mixed)			*			*			*
20. 2-chloronaphthalene			*		(10)	1			*

* Pollutant not detected

( ) Reported as less than value

TABLE V-13 (Cont.)

Toxic Pollutant	Water Supply Med.	Water Supply Max.	Water Supply No.	Raw Wastewater Med.	Raw Wastewater Max.	Raw Wastewater No.	Secondary Effluent Med.	Secondary Effluent Max.	Secondary Effluent No.
	Concentration Observed, micrograms/liter								
21. 2,4,6-trichlorophenol			*	20	27	4		19	1
22. parachlorometacresol			*		168	1		32	1
23. chloroform	39	1360	6	48	642	11	8.5	58	6
24. 2-chlorophenol			*		78	1		5.9	1
25. 1,2-dichlorobenzene			*	2.0	287	7	10	20	4
26. 1,3-dichlorobenzene			*			*			*
27. 1,4-dichlorobenzene			*	110	215	2	0.8	1.5	2
28. 3,3'-dichlorobenzidine			*			*			*
29. 1,1-dichloroethylene			*		(5)	1			*
30. 1,2-trans-dichloroethylene			*			*			*
31. 2,4-dichlorophenol			*	26	41	2			*
32. 1,2-dichloropropane			*		100	1			*
33. 1,3-dichloropropylene		0.8	1			*			*
34. 2,4-dimethylphenol			*			*		8.0	1
35. 2,4-dinitrotoluene			*			*			*
36. 2,6-dinitrotoluene			*		54	1			*
37. 1,2-diphenylhydrazine			*		22	1			*
38. ethylbenzene			*	54	2840	20	63	3018	8
39. fluoranthene			*			*			*
40. 4-chlorophenyl phenyl ether			*			*			*

* Pollutant not detected
( ) Reported as less than value

TABLE V-13 (Cont.)

Toxic Pollutant	Concentration Observed, micrograms/liter								
	Water Supply			Raw Wastewater			Secondary Effluent		
	Med.	Max.	No.	Med.	Max.	No.	Med.	Max.	No.
41. 4-bromophenyl phenyl ether			*			*			*
42. bis(2-chloroisopropyl) ether			*			*			*
43. bis(2-chloroethoxy) methane			*			*			*
44. methylene chloride	(5)	(5)	2	47	110	3	(5)	(5)	3
45. methyl chloride			*		(5)	1			*
46. methyl bromide			*			*			*
47. bromoform			*			*			*
48. dichlorobromomethane	(5)	(5)	2		6.6	1			*
49. trichlorofluoromethane			*			*	90	2138	3
50. dichlorodifluoromethane			*			*			*
51. chlorodibromomethane			*			*			*
52. hexachlorobutadiene			*			*			*
53, hexachlorocyclopentadiene			*			*			*
54. isophorone			*			*			*
55. naphthalene			*	44	410	19	22	255	5
56. nitrobenzene			*			*			*
57. 2-nitrophenol			*			*		4.1	1
58. 4-nitrophenol			*			*		(10)	1
59. 2,4-dinitrophenol			*			*			*
60. 4,6-dinitro-o-cresol			*			*			*

* Pollutant not detected
( ) Reported as less than value

TABLE V-13 (Cont.)

Toxic Pollutant	Concentration Observed, micrograms/liter								
	Water Supply			Raw Wastewater			Secondary Effluent		
	Med.	Max.	No.	Med.	Max.	No.	Med.	Max.	No.
101. heptachlor epoxide			*			*			*
102. alpha-BHC			*			*			*
103. beta-BHC			*			*			*
104. gamma-BHC (lindane)			*			*			*
105. delta-BHC			*			*			*
106. PCB-1242 (Arochlor 1242)			*			*			*
107. PCB-1254 (Arochlor 1254)			*			*			*
108. PCB-1221 (Arochlor 1221)			*			*			*
109. PCB-1232 (Arochlor 1232)			*			*			*
110. PCB-1248 (Arochlor 1248)			*			*			*
111. PCB-1260 (Aroclor 1260)			*			*			*
112. PCB-1016 (Aroclor 1016)			*			*			*
113. toxaphene			*			*			*
114. antimony	(5)	48	6	7.0	170	23	4.5	684	16
115. arsenic	(5)	(5)	4	10	200	14	39	160	8
116. asbestos (fibrous)#									
117. beryllium	(5)	(5)	4	(5)	40	5	(5)	(5)	5
118. cadmium	(10)	(10)	5	(5)	46	22	6	13	15
119. chromium	(5)	(5)	5	14	880	37	20	1800	27
120. copper	10	47	6	40	2400	40	32	290	28

* Pollutant not detected
\# Pollutant not analyzed for
( ) Reported as less than value

TABLE V-13 (Cont.)

Toxic Pollutant	Concentration Observed, micrograms/liter								
	Water Supply			Raw Wastewater			Secondary Effluent		
	Med.	Max.	No.	Med.	Max.	No.	Med.	Max.	No.
121. cyanide	11	22	4	8.0	39	10	12	980	5
122. lead	(5)	45	6	35	750	26	46	120	16
123. mercury	0.2	0.8	4	0.6	4	10	0.4	0.7	7
124. nickel	(5)	47	6	54	300	32	70	150	18
125. selenium	(5)	23	6	35	740	10	47	97	4
126. silver	(5)	17	6	32	130	26	25	140	15
127. thallium	3	3	4	3	9	5	3.0	18	4
128. zinc	60	4540	12	190	7900	45	200	38000	30
129. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) #									

* Pollutant not detected
\# Pollutant not analyzed for
( ) Reported as less than value

samples were collected for 14 mills, with two pairs of mills using the same supply. In other words, 12 separate water supply samples were collected and analyzed.

Table V-13 includes all 129 of the toxic pollutants, whether detected in textile wastes or not, and it shows that 65 toxic pollutants, including all but two of the pesticides and all of the PCB's were not detected in any wastewater sample. An additional 15 toxic pollutants were detected only once, i.e., in samples from only one source stream.

With the exception of zinc, the maximum concentration of any toxic pollutant detected in raw wastewater was less than 5 mg/l; zinc was detected at just under 8 mg/l.

The field sampling program differed from the usual screening and verification programs prescribed by EPA in that the number of mills in each subcategory was changed to more closely fit the distribution of mills in the industry. Because of the wide diversity within the manufacturing processes used by the textile industry, it was recognized that the screening phase should encompass more than one mill in each subcategory. That this expanded approach was correct is indicated by the number of toxic pollutants that were detected at only one of 44 mills, as discussed in more detail in Section VI. The findings of the field sampling program also indicate that a verification program that adhered exactly to the EPA protocol would not have produced different results because many of the toxic pollutants were found infrequently and probably would not have shown up during the verification phase. On the other hand, the field sampling program did clearly identify those toxic pollutants that are generally used in the various subcategories of the textile industry.

<u>Toxic Pollutants - Field Sampling Data</u>

Based on the data from the field sampling program, the most frequently occurring toxic pollutants within each subcategory of the industry were identified. Both raw wastewater and secondary treated effluent samples were reviewed, and all values of 10 ug/l and above were included. The maximum concentration detected and the number of mills where the pollutant was detected were considered in determining the significance of the pollutants.

It should be noted that the number of mills sampled was necessarily limited, and this information is not intended as an all-inclusive listing. Subsequent data may result in other toxic pollutants being observed.

<u>Subcategory 1 - Wool Scouring</u>. Three mills in the Wool Scouring Subcategory were sampled for toxic pollutants. The following pollutants were found to be most significant:

8. 1,2,4-trichlorobenzene
65. phenol
66. bis (2-ethylhexyl) phthalate
68. di-ni-butyl phthalate
70. diethyl phthalate
85. tetrachloroethylene
87. trichloroethylene
115. arsenic
118. cadmium
119. chromium
120. copper
121. cyanide
122. lead
124. nickel
126. silver
128. zinc

Subcategory 2 - Wool Finishing. Two mills in the Wool Finishing Subcategory were sampled for toxic pollutants. The following pollutants were found to be most significant:

25. 1,2-dichlorobenzene
27. 1,4-dichlorobenzene
38. ethyl benzene
55. naphthalene
64. pentachlorophenol
66. bis(2-ethylhexyl) phthalate
87. trichloroethylene
118. cadmium
119. chromium
120. copper
123. mercury
124. nickel
128. zinc

Subcategory 3 - Low Water Use Processing. Two mills in the Low Water Use Processing Subcategory were sampled for toxic pollutants. The following pollutants were found to be most significant:

23. chloroform
87. trichloroethylene
120. copper
122. lead
124. nickel
126. silver
128. zinc

Subcategory 4 - Woven Fabric Finishing. Sixteen mills in the Woven Fabric Finishing Subcategory were sampled for toxic pollutants. The following pollutants were found to be most significant:

4. benzene
7. (mono) chlorobenzene
8. 1,2,4-trichlorobenzene
21. 2,4,6-trichlorophenol
22. parachlorometacresol
23. chloroform
24. 2-chlorophenol
32. 1,2-dichloropropane
38. ethyl benzene
44. methylene chloride
55. naphthalene
62. N-nitrosodiphenylamine
64. pentachlorophenol
65. phenol
66. bis(2-ethylhexyl) phthalate
68. di-n-butyl phthalate
70. dimethyl phthalate
86. toluene
87. trichloroethylene
114. antimony
115. arsenic
118. cadmium
119. chromium
120. copper
122. lead
123. mercury
124. nickel
126. silver
128. zinc

<u>Subcategories 5a and 5b - Knit Fabric Finishing</u>. Six mills in the Knit Fabric Finishing Subcategory were sampled for toxic pollutants. The following pollutants were found to be most significant:

8. 1,2,4-trichlorobenzene
23. chloroform
25. 1,2-dichlorobenzene
38. ethyl benzene
55. naphthalene
64. pentachlorophenol
65. phenol
66. bis(2-ethylhexyl) phthalate
69. diethyl phthalate
70. dimethyl phthalate
85. tetrachloroethylene
86. toluene
87. trichloroethylene

114. antimony
115. arsenic
118. cadmium
119. chromium
120. copper
121. cyanide
122. lead
124. nickel
126. silver
128. zinc

Subcategory 5c - Hosiery Products. Three mills in the Knit Fabric Finishing - Hosiery Products Subcategory were sampled for priority pollutants. The following pollutants were found to be most significant:

3. acrylonitrile
21. 2,4,6-trichlorophenol
23. chloroform
55. naphthalene
62. N-nitrosodiphenylamine
65. phenol
66. bis(2-ethylhexyl) phthalate
67. tetrachloroethylene
119. chromium
126. silver
128. zinc

Subcategory 6 - Carpet Finishing. Three mills in the Carpet Finishing Subcategory were sampled for toxic pollutants. The following pollutants were found to be most significant:

23. chloroform
37. diphenylhydrazine
55. naphthalene
65. phenol
66. bis(2-ethylhexyl) phthalate
118. cadmium
119. chromium
120. copper
121. cyanide
123. mercury
124. nickel
126. silver
128. zinc

Subcategory 7 - Stock & Yarn Finishing. Six mills in the Stock & Yarn Finishing Subcategory were sampled for toxic pollutants. The following pollutants were found to be most significant:

23. chloroform
55. naphthalene
65. phenol
66. bis(2-ethylhexyl) phthalate
69. diethyl phthalate
70. dimethyl phthalate
87. trichloroethylene
114. antimony
118. cadmium
119. chromium
120. copper
122. lead
123. mercury
124. nickel
126. silver
128. zinc

Subcategory 8 - Nonwoven Manufacturing. Three mills in the Nonwoven Manufacturing Subcategory were sampled for toxic pollutants. The following pollutants were found to be most significant:

4. benzene
23. chloroform
55. naphthalene
66. bis(2-ethylhexyl) phthalate
67. butyl benzyl phthalate
86. toluene
118. cadmium
120. copper
121. cyanide
122. lead
124. nickel
126. silver
128. zinc

Subcategory 9 - Felted Fabric Processing. One mill in the Felted Fabric Processing Subcategory was sampled for toxic pollutants. The following pollutants were found to be most significant:

55. naphthalene
65. phenol
66. bis(2-ethylhexyl) phthalate
87. trichloroethylene

Other Sources of Information

Various chemical and textile industry literature sources were reviewed to collect general information about usage of the toxic pollutants. In addition, selected specialists within the industry were asked to provide information about certain of the pollutants. In some cases, the results were opinions from chemists and others and were based on the individual's experience only, without additional study or research. In other cases, special study committees were convened by trade associations to gather information from the membership about certain of the toxic pollutants. Except for some of the metals, the findings of these committees were qualitative because of the absence of quantitative historical information. Two committees, one from the American Textile Manufacturers Institute (ATMI) and one from the Dyes Environmental and Toxicology Organization (DETO), were particularly helpful in providing useful information.

ATMI organized a special Task Group on Toxic Pollutants and it reviewed in detail a list of 52 toxic pollutants that were neither clearly present nor clearly absent in textile mill wastewaters. This list was based on the literature and some early results of the field sampling program. Information was requested about the likelihood of each pollutant being present and, if so, information about potential sources. The Task Group classified each pollutant as:

Probable -- definitely established as present in product or process. Pollutant levels have been established in only a few cases but the evidence is sound.

Possible -- known or suspected as an intermediate or contaminant of products and processes being used. Many in this category could be entering in an auxiliary manner such as maintenance products and agricultural contaminants in process water.

Not Likely -- unable to find data to support the presence of these chemicals.

For each "probable" or "possible" pollutant, possible sources were suggested. This information is incorporated in the discussions of the sources of the individual toxic pollutants in Section VI.

The other industry-related group was the Ecology Committee of Dyes Environmental and Toxicology Organization, Inc. (DETO). DETO comprises 18 member companies that, in aggregate, produce over 90 percent of the dyes manufactured in the United States. The Ecology Committee carried out a survey of the DETO membership to determine which of the toxic pollutants in textile wastewaters might originate in dyes. The list of pollutants was narrowed to 40 that the committee believed could possibly be present in commercial dye products. Because of time limitations, the committee focused on dye products for which domestic sales (1976) exceeded 90,000 kg (approximately 20,000 pounds) per year and for which there are more than two producers. The list of dyes numbered 70. Questionnaires were sent to and received from all 18 member companies, and in addition to the 70 listed dyes, responses were received for an additional 81 dyes, for a total of 151 dye products representing 55.3 percent of the 113,380 metric tons (approximately 250 million pounds) sold in 1976. Six toxic pollutants (chromium, copper, parachlorometacresol, pentachlorophenol, phenol, and zinc) were classed as "believed present in (some) commercial dyes at greater than 0.1%" and 19 additional pollutants were classified as "believed present in (some) commercial dyes at less than 0.1%." The results of the DETO survey are presented in more detail in the discussion of the sources of the individual pollutant parameters in Section VI.

The ATMI Task Force reports and the DETO survey and results are provided in Appendix E.

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

The wastewater parameters and individual pollutant constituents that are to be considered in establishing effluent limitations guidelines, standards of performance, and pretreatment standards are presented in this section. They are grouped into three separate classes: conventional, non-conventional, and toxic pollutants. The toxic pollutants are further classified into three groups, based on their evaluated significance in textile mill wastewaters. The information sources used in selecting the pollutant parameters in each class are described in Section V.

CONVENTIONAL POLLUTANTS

The conventional pollutant parameters selected for the Textile Mills Point Source Category are the following:

Biochemical Oxygen Demand (BOD)
Total Suspended Solids (TSS)
Oil & Grease
pH - Acidity and Alkalinity

Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand (BOD) is the quantity of oxygen required for the biological and chemical oxidation of waterborne substances under ambient or test conditions. Materials which may contribute to the BOD include: carbonaceous organic materials usable as a food source by aerobic organisms; oxidizable nitrogen derived from nitrates, ammonia and organic nitrogen compounds which serve as food for specific bacteria; and certain chemically oxidizable materials such as ferrous iron, sulfides, sulfite, etc. which will react with dissolved oxygen or are metabolized by bacteria. In most industrial and municipal wastewaters, the BOD derives principally from organic materials and from ammonia (which is itself derived from animal or vegetable matter).

The BOD of a waste exerts an adverse effect upon the dissolved oxygen resources of a body of water by reducing the oxygen available to fish, plant life, and other aquatic species. Conditions can be reached where all of the dissolved oxygen in the water is utilized resulting in anaerobic conditions and the production of undesirable gases such as hydrogen sulfide and methane. The reduction of dissolved oxygen can be detrimental to fish populations, fish growth rate, and organisms used as fish food. A total lack of oxygen due to excessive BOD can result in the death of all aerobic aquatic inhabitants in the affected area.

Water with a high BOD indicates the presence of decomposing organic matter and associated increased bacterial concentrations that degrade its quality and potential uses. A by-product of high BOD concentrations can be increased algal concentrations and blooms which result from decomposition of the organic matter and which form the basis of algal populations.

The BOD5 (5-day BOD) test is used widely to estimate the pollutional strength of domestic and industrial wastes in terms of the oxygen that they will require if discharged into receiving streams. The test is an important one in water pollution control activities. It is used for pollution control regulatory activities, to evaluate the design and efficiencies of wastewater treatment works, and to indicate the state of purification or pollution of receiving bodies of water.

Complete biochemical oxidation of a given waste may require a period of incubation too long for practical analytical test purposes. For this reason, the 5-day period has been accepted as standard, and the test results have been designated as BOD5 . Specific chemical test methods are not readily available for measuring the quantity of many degradable substances and their reaction products. Reliance in such cases is placed on the collective parameter, BOD5, which measures the weight of dissolved oxygen utilized by microorganisms as they oxidize or transform the gross mixture of chemical compounds in the wastewater. The biochemical reactions involved in the oxidation of carbon compounds are related to the period of incubation. The five-day BOD normally measures only 60 to 80 percent of the carbonaceous biochemical oxygen demand of the sample, and for many purposes, this is a reasonable parameter. Additionally, it can be used to estimate the gross quantity of oxidizable organic matter.

The BOD5 test is essentially a bioassay procedure which provides an estimate of the oxygen consumed by microorganisms utilizing the degradable matter present in a waste under conditions that are representative of those that are likely to occur in nature. Standard conditions of time, temperature, suggested microbial seed, and dilution water for the wastes have been defined and are incorporated in the standard analytical procedure. Through the use of this procedure, the oxygen demand of diverse wastes can be compared and evaluated for pollution potential and to some extent for treatability by biological treatment processes.

Because the BOD test is a bioassay procedure, it is important that the environmental conditions of the test be suitable for the microorganisms to function in an uninhibited manner at all times. This means that toxic substances must be absent and that the necessary nutrients, such as nitrogen, phosphorus, and trace elements, must be present.

Total Suspended Solids (TSS)

Suspended solids include both organic and inorganic materials. The inorganic compounds include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, and animal and vegetable waste products. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic plants.

Suspended solids in water interfere with many industrial processes, cause foaming in boilers and incrustations on equipment exposed to such water, especially as the temperature rises. They are undesirable in process water used in the manufacture of steel, in the textile industry, in laundries, in dyeing, and in cooling systems.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often damaging to the life in water. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy that habitat. When of an organic nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a food source for sludgeworms and associated organisms.

Disregarding any toxic effect attributable to substances leached out by water, suspended solids may kill fish and shellfish by causing abrasive injuries and by clogging the gills and respiratory passages of various aquatic fauna.

Indirectly, suspended solids are inimical to aquatic life because they screen out light, and they promote and maintain the development of noxious conditions through oxygen depletion. This results in the killing of fish and fish food organisms. Suspended solids also reduce the recreational value of the water.

Oil & Grease

Because of widespread use, oil and grease occur often in wastewater streams. These oily wastes may be classified as follows:

1. Light Hydrocarbons - These include light fuels such as gasoline, kerosene, and jet fuel, and miscellaneous solvents used for industrial processing, degreasing, or cleaning purposes. The presence of these

light hydrocarbons may make the removal of other heavier oily wastes more difficult.

2. Heavy Hydrocarbons, Fuels and Tar - These include the crude oils, diesel oils, #6 fuel oil, residual oils, slop oils and, in some cases, asphalt and road tar.

3. Lubricants and Cutting Fluids - These generally fall into two classes: non-emulsifiable oils such as lubricating oils and greases and emulsifiable oils such as water soluble oils, rolling oils, cutting oils, and drawing compounds. Emulsifiable oils may contain fat, soap, or various other additives.

4. Vegetable and Animal Fats and Oils - These originate primarily from processing of foods and natural products.

These compounds can settle or float and may exist as solids or liquids depending upon factors such as method of use, production process, and temperature of wastewater.

Oils and grease even in small quantities cause troublesome taste and odor problems. Scum lines from these agents are produced on water treatment basin walls and other containers. Fish and water fowl are adversely affected by oils in their habitat. Oil emulsions may adhere to the gills of fish causing suffocation, and the flesh of fish is tainted when microorganisms that were exposed to waste oil are eaten. Deposition of oil in the bottom sediments of water can serve to inhibit normal benthic growth. Oil and grease exhibit an oxygen demand.

Levels of oil and grease which are toxic to aquatic organisms vary greatly, depending on the type and the species susceptibility. However, it has been reported that crude oil in concentrations as low as 0.3 mg/l is extremely toxic to fresh-water fish. It has been recommended that public water supply sources be essentially free from oil and grease.

Oil and grease in quantities of 100 l/sq km (10 gallons/sq mile) show up as a sheen on the surface of a body of water. The presence of oil slicks prevent the full aesthetic enjoyment of water. The presence of oil in water can also increase the toxicity of other substances being discharged into the receiving bodies of water. Municipalities frequently limit the quantity of oil and grease that can be discharged to their wastewater treatment systems by industry.

Wool wax is a substantial pollutant in the Wool Scouring subcategory of the textile industry; in other subcategories, materials measured as grease and oil are much less troublesome.

pH - Acidity and Alkalinity

Although not a specific pollutant, pH is related to the acidity or alkalinity of a wastewater stream. It is not a linear or direct measure of either; however, it may properly be used as a surrogate to control both excess acidity and excess alkalinity in water. The term pH is used to describe the hydrogen ion - hydroxyl ion balance in water. Technically, pH is the hydrogen ion concentration or activity present in a given solution. pH numbers are the negative logarithm of the hydrogen ion concentrations. A pH of 7 generally indicates neutrality or a balance between free hydrogen and free hydroxyl ions. Solutions with a pH above 7 indicate that the solution is alkaline, while a pH below 7 indicates that the solution is acidic.

Knowledge of the pH of water or wastewater is useful in determining necessary measures for corrosion control, pollution control, and disinfection. Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and such corrosion can add constituents to drinking water such as iron, copper, zinc, cadmium and lead. Low pH waters not only tend to dissolve metals from structures and fixtures but also tend to redissolve or leach metals from sludges and bottom sediments. The hydrogen ion concentrations can affect the taste of the water and at a low pH, water tastes sour.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Even moderate changes from acceptable criteria limits of pH are deleterious to some species. The harmful effect on aquatic life of many materials is increased by changes in the water pH. For example, metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. Similarly, the toxicity of ammonia is a function of pH. The bactericidal effect of chlorine in most cases is less as the pH increases, and it is economically advantageous to keep the pH close to 7.

NON-CONVENTIONAL POLLUTANTS

The non-conventional pollutant parameters selected for the Textile Mill Point Source Category are the following:

Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) is a purely chemical oxidation test devised as an alternate method of estimating the total oxygen demand of a wastewater. Since the method relies on the oxidation-reduction system of chemical analyses rather than on biological factors, it is more precise, accurate, and rapid than the BOD test. The COD test is widely used to estimate the total oxygen demand (ultimate rather than 5-day BOD) to oxidize the compounds in a wastewater. It is based on the fact that organic compounds, with a few exceptions, can be oxidized by strong chemical oxidizing agents under acidic conditions with the assistance of certain inorganic catalysts.

The COD test measures the oxygen demand of compounds that are biologically degradable and of many that are not. Pollutants which are measured by the BOD5 test will be measured by the COD test. In addition, pollutants which are more resistant to biological oxidation will also be measured as COD. COD is a more inclusive measure of oxygen demand than is BOD5 and will result in higher oxygen demand values than will the BOD5 test.

The compounds which are more resistant to biological oxidation are becoming of greater and greater concern not only because of their slow but continuing oxygen demand on the resources of the receiving water, but also because of their potential health effects on aquatic life and humans. Many of these compounds result from industrial discharges and some have been found to have carcinogenic, mutagenic and similar adverse effects, either singly or in combination. Concern about these compounds has increased as a result of demonstrations that their long life in receiving water - the result of a slow biochemical oxidation rate - allows them to contaminate downstream water intakes. The commonly used systems of water purification are not effective in removing these types of materials and disinfection, such as chlorination, may convert them into even more hazardous materials.

Thus the COD test measures organic matter which exerts an oxygen demand and which may affect the health of the people. It is a useful analytical tool for pollution control activities. It provides a more rapid measurement of the oxygen demand and an estimate of organic compounds which are not measured in the BOD5 test.

Color

Color is defined as either "true" or "apparent." In Standard Methods for the Examination of Water and Wastewater (8), the true color of water is defined as "the color of water from which the turbidity has been removed." Apparent colors include "not only the color due to substances in solution, but also due to suspended matter."

Color in textile wastewater results from equipment washup, textile wash water and from dye not exhausted in the dyeing process.

Color bodies interfere with the transmission of light within the visible spectrum which is absorbed and used in the photosynthetic process of microflora. Color will affect the aquarian ecosystem balance by changing the amount of light transmitted and may lead to species turnover.

Color bodies discharged to waterways alter the natural stream color and thereby become an aesthetic pollutant. Unnatural receiving water color detracts from the visual appeal and recreational value of the waterways.

Color, when discharged to receiving waters, may have a detrimenal effect on downstream municipal and industrial water users. Color is not treated for in conventional water treatment systems and when passed to users may result in consumer discontent and may also interfere with industrial processes which demand high quality water.

Color is found in wastewater throughout the textile industry. Some colors are water soluble and some are not (dispersed and vat dyes). Biodegradability of many of the dyes responsible for the color is highly variable, and toxicity and effect on aquatic life of many of these dyes is unknown. Many hues are used in dyeing, and may appear in wastes; their combination in waste streams frequently generates a gray or black color. There is no universally accepted monitoring method, although an analytical procedure developed by the American Dye Manufacturers Institute (ADMI) has been found to evaluate color in textile effluents most accurately. The analytical procedure and the calculations required to evaluate color are reported in Appendix A of the Point Source Development Document (1).

TOXIC POLLUTANTS

Because there are several manufacturing processes that are common to more than one subcategory of the textile industry, the data from all mills in the field sampling program were combined in order to identify the toxic pollutants that are most significant for the entire industry.

Using the data from the field sampling program and the other sources of information described in Section V, each of the 129 toxic pollutants was evaluated in terms of its significance in textile mill wastewaters. The results are presented below in three groups. The first group includes 17 organic compounds, cyanides, and 11 metals. Most of these were found frequently and all were detected at least once in secondary treatment effluents at concentrations of 10 ug/l or greater, except for mercury. The second group includes those toxic pollutants that are potentially significant in textile mill wastes either in terms of measured raw waste or treated effluent concentrations or frequency of detection. None were detected in secondary treatment effluents at concentrations of 10 ug/l or above. Some Group 2 pollutants were not detected, but were either established as potentially present in mill wastes by industrial sources (ATMI or DETO) or suggested as possibly present as an intermediate or contaminant. The third group includes 27 organic compounds plus asbestos that are regarded as unlikely constituents of textile wastewaters.

The 10 ug/l level was selected as an interim limit for the textile industry in order to focus upon those toxic pollutants that potentially will cause the most serious problems. There exist some questions about the reliability of results below 10 ug/l for some of the toxic pollutants because of limitations in the analytical procedures to extract, concentrate, and clean up samples of textile mill wastewaters. Also, at this time, there is little information available about treatment options that can control concentrations at levels below 10 ug/l.

Group 1 - Most Significant in Textile Wastewaters

The toxic pollutants judged to be most significant in textile mill wastewaters are the following:

3. acrylonitrile
4. benzene
8. 1,2,4-trichlorobenzene
21. 2,4,6-trichlorophenol
22. parachlorometacresol
23. chloroform
25. 1,2-dichlorobenzene
38. ethylbenzene
49. trichlorofluoromethane
55. naphthalene
63. N-nitrosodi-n-propylamine
64. pentachlorophenol
65. phenol
66. bis(2-ethylhexyl) phthalate
85. tetrachloroethylene
86. toluene
87. trichloroethylene
114. antimony
115. arsenic
118. cadmium
119. chromium
120. copper
121. cyanide
122. lead
123. mercury
124. nickel
125. selenium
126. silver
128. zinc

A brief discussion of the traditional uses and possible sources in textile mill operations of each of the Group 1 toxic pollutants follows.

Acrylonitrile. Acrylonitrile is an unsaturated synthetic organic compound primarily used in the production of acrylic and modacrylic fibers, nitrile rubber, and plastics. Annual production totals approximately 1.5 billion pounds.

Sources of acrylonitrile reported by the textile industry include fibers and other raw materials, laboratory operations, dyes, and latex compounds. Out of 418 questionnaire returns, 32 indicated "known or suspected presence" in mill wastewaters. Despite this indication of rather common usage, acrylonitrile was detected at only 1 mill of 44 in the field sampling program.

Benzene. Benzene is produced principally from coal tar distillation and from petroleum by catalytic reforming of light naphthas from which it is isolated by distillation or solvent extraction. The broad utility spectrum of benzene (commercially sometimes called "Benzol") includes: extraction and rectification; as an intermediate for synthesis in the chemical and pharmaceutical industries; the preparation and use of inks in the graphic arts industries; as a thinner for lacquers; as a degreasing and cleaning agent; as a solvent in the rubber industry; as an antiknock fuel additive; and as a general solvent in laboratories. Industrial processes involving the production of benzene and chemical synthesis usually are performed in sealed and protected systems. Currently, benzene is used by the chemical industry at the rate of 1.4 billion gallons annually. Sources of benzene reported by the textile industry include raw materials, use as a solvent, and dyes, although it was not one of 25 priority pollutants suggested by DETO as likely to be present in the 151 dye products that represent the bulk of the dye industry's commercial volume by weight. Out of 418 questionnaire returns, 32 indicated "known or suspected presence" in mill wastewaters. Benzene was detected at greater than 10 ug/l levels in 5 mills in the field sampling program, and at lesser levels in 6 mills. With one exception, however, levels in secondary effluents were "less than 5 ug/l" or undetectable.

1,2,4-Trichlorobenzene. The compound 1,2,4-trichlorobenzene is a chlorinated benzene and is one of the class of aromatic organic compounds characterized by the substitution of from one to six chlorine atoms on the benzene nucleus. Other trichlorobenzene isomers are 1,2,3-trichlorobenzene, and 1,3,5-trichlorobenzene but these are not used in significant quantity. The compound has seen use as a dye carrier in the textile industry, a herbicide intermediate, a heat transfer medium, a dielectric fluid in transformers, a degreaser, a lubricant, and as a potential insecticide against termites. During the period 1973-1974, production and use of trichlorobenzenes resulted in approximately 8,182 metric tons entering the aquatic environment.

Sources of trichlorobenzene reported by the textile industry include usage as a dye carrier in dyeing polyester fiber, laboratory operations, scouring in the dyeing process, and as a raw material. Out of 418 questionnaire returns, 86 indicated "known or suspected presence" in mill wastewaters. It was detected at 10 ug/l or greater (often much greater) in 10 of 44 mills in the field sampling program.

<u>2,4,6-Trichlorophenol</u>. The compound 2,4,6-trichlorophenol belongs to the chemical class known as chlorinated phenols. This class represents a group of commercially produced, substituted phenols and cresols referred to as chlorophenols and chlorocresols. Chlorinated phenols are used as intermediates in the synthesis of dyes, pigments, phenolic resins, pesticides, and herbicides. Certain chlorophenols also are used directly as flea repellents, fungicides, wood preservatives, mold inhibitors, antiseptics, disinfectants, and antigumming agents for gasoline. Sources of trichlorophenol in the textile industry include possible usage as a preservative and as a constituent or impurity in carrier systems for dyeing polyester. Out of 418 questionnaire returns, 7 indicated "suspected presence" in mill wastewaters. Trichlorophenol was detected in the wastes at five textile mills during the field sampling program.

<u>Parachlorometacresol</u>. Parachlorometacresol belongs to the chemical class known as chlorinated phenols. This class represents a group of commercially produced, substituted phenols and cresols referred to as chlorophenols and chlorocresols. Chlorinated phenols are used as intermediates in the synthesis of dyes, pigments, phenolic resins, pesticides, and herbicides. Certain chlorophenols also are used directly as flea repellents, fungicides, wood preservatives, mold inhibitors, antiseptics, disinfectants, and antigumming agents for gasoline.

Sources of parachlorometacresol reported by the industry include its possible use as a biocide or disinfectant in dyestuffs, dye carrier systems, and in industrial cleaning compounds. The survey of the dye manufacturing industry conducted by DETO indicated that this compound was one of six toxic pollutants that could be present at levels greater than 0.1 percent in some commercial dyes, resulting in possible raw waste loadings from 100 to 1,000 ug/l. Of 418 questionnaire returns, 3 indicated "suspected presence" in the mill wastewater. This compound was detected at two mills in the field sampling program.

<u>Chloroform</u>. Chloroform was initially employed as an anesthetic agent; however, it has become obsolete as a widely used anesthetic in favor of other agents with more desirable properties. The major uses of

chloroform at present are as a solvent and as an intermediate in the production of refrigerants, plastics, and pharmaceuticals. Chloroform seems to be ubiquitous in the environment in trace amounts; discharges into the environment result largely from chlorination treatment of water and wastewater.

Sources of chloroform reported by the textile industry include its use in dyeing operations and in the laboratory. Although only 7 out of 418 questionnaire returns indicated "known or suspected presence" of chloroform, it was detected at levels greater than 10 ug/l in the wastewaters from 12 of 44 mills in the field sampling program, and at lesser levels in 2 additional mills.

1,2-Dichlorobenzene. The compound 1,2-dichlorobenzene belongs to the chemical class known as dichlorobenzenes. This class of compounds is represented by three isomers: 1,2-dichloro-, 1,3-dichloro-, and 1,4-dichloro-benzene. Both 1,2-dichloro- and 1,4-dichloro-benzene are produced almost entirely as byproducts from the production of monochlorobenzene. Production in 1975 consisted of 24,801 metric tons of 1,2-dichlorobenzene and 20,754 metric tons of 1,4-dichlorobenzene. The estimated losses of dichlorobenzenes during the production of monochlorobenzene are 20.5 kg/metric ton to wastewater and 22.22 kg/metric ton to land disposal. The major uses of 1,2-dichlorobenzene are as a process solvent in the manufacturing of toluene diisocyanate, and as an intermediate in the synthesis of dyestuffs, herbicides, and degreasers.

In the survey carried out by DETO, 1,2-dichlorobenzene was judged to be present in some commercial dyes, but at levels less than 0.1 percent. This is the only reported source of this compound in textile mill wastewaters. Out of 418 questionnaire returns, 18 indicated "known or suspected presence" in the wastewaters. In the field sampling program, this pollutant was detected at greater than 10 ug/l at 4 mills, and at lesser concentrations at 5 additional mills.

Ethylbenzene. Ethylbenzene is an alkyl substituted aromatic compound employed as an antiknock compound for airplane engine fuel, as a lacquer diluent, in the synthesis of styrols for resins, as a solvent for paraffin waxes, and in the production of cellulose acetate silks. It is only slightly soluble in water, but will dissolve in organic solvents.

Ethylbenzene was one of 25 toxic pollutants that may be present in some commercial dyes, at less than 0.1 percent, according to the survey carried out by DETO. Its presence in dyestuffs and as a solvent in print pastes was also reported by individual mills. While only 9 out of 418 questionnaire returns indicated "known or suspected presence" in mill wastewaters, ethylbenzene was detected at 23 of 44 mills in the field sampling program. Concentration levels of 10 ug/l or more were measured in the wastewaters from 19 of the 23 mills.

Trichlorofluoromethane. Trichlorofluoromethane belongs to the class of compounds known as halomethanes. These compounds are a subcategory of the halogenated hydrocarbons. Tricholorofluoromethane is also known as trichloromonofluoromethane, fluorotrichloromethane, Freon 11, Frigen 11, and Acton 9. Freon compounds are organic compounds that contain fluorine. They have a high degree of chemical stability, relatively low toxicity, and are nonflammable. They have found many applications ranging from use as propellants to use as refrigerants and solvents.

Trichlorofluoromethane may be used as a refrigerant and an aerosol propellant in the textile industry. None of the questionnaire returns indicated any likelihood of this compound being in the mill wastewaters, although one industry source speculated that it might result from laboratory operations. It was detected in treated effluents at five mills in the field sampling program, but not in the raw wastes at these mills.

Naphthalene. Naphthalene, a bicyclic aromatic compound, is the most abundant single constituent of coal tar. It is also found in cigarette smoke. This compound is used as an intermediate in the production of dye compounds and in the formation of solvents, lubricants, and motor fuels. The largest use of napthalene in 1975 (58 percent of total use) was for the synthesis of phthalic anhydride. It has also been used as a moth repellent and insecticide, as well as an antihelminthic and as an intestinal antiseptic and vermicide.

Sources of naphthalene in textile mill wastewaters reported by the industry are dyes and possibly laboratory operations. The direct dyes were cited as specific sources of this compound. The DETO survey results indicated that this toxic pollutant was likely to be present in some dyes at levels less than 0.1 percent. Out of 418 questionnaire returns, 55 indicated "known or suspected presence" in mill wastewaters. In the field sampling program, it was detected at 10 ug/l or greater concentrations at 15 mills and at lesser levels in 7 additional mills.

N-nitrosodi-n-propylamine. The compound N-nitrosodi-n-propylamine belongs to the chemical class known as nitrosamines. The organic nitrosocompounds are a large group of chemicals characterized by a nitroso group (N=O) that is attached to the nitrogen of a secondary amine. Patent applications show potential uses of nitrosamines in the manufacture of rubber, dyestuffs, gasoline additives, lubricating oils, explosives, insecticides, fungicides, dielectric fluids, acrylonitrile, plasticizers, industrial solvents, and hydrazine. At present, two major industries are involved in handling nitrosamines:

organic chemicals manufacturing and rubber processing. Diphenylnitrosamine is the only nitrosamine that is produced in quantities greater than 450 kg. It is used as a vulcanizing retarder in rubber processing and in pesticides. Other nitrosamines are not produced commercially except as research chemicals.

Limited industry information suggests that N-nitrosodi-n-propylamine may possibly be present in textile mill wastewaters from contamination of certain chemicals, perhaps some dyes. None of the 418 questionnaire returns indicated "known or suspected presence" in mill wastes. In the field sampling program, this compound was detected at only two mills, at relatively low concentrations, and only in the effluents from secondary treatment systems.

Pentachlorophenol. Pentachlorophenol (PCP) is a commercially produced bactericide, fungicide, and slimicide used primarily for the preservation of wood, wood products, and other materials. As a chlorinated hydrocarbon, its biological properties have also resulted in its use as a herbicide, insecticide, and molluscicide.

Pentachlorophenol is used in the textile industry as a preservative in dyes. In the DETO survey results, this was one of six toxic pollutants that could be expected in some commercial dyes at levels greater than 0.1 percent, resulting in possible raw textile wastewater concentrations in the 100 to 1,000 ug/l range. Out of 418 questionnaire returns, 17 indicated "known or suspected presence" in mill wastewaters. In the field sampling program, pentachlorophenol was detected at 10 ug/l or greater levels in 10 mills, and at lower levels in 2 additional mills.

Phenol. Phenol is an aromatic compound that has a hydroxyl group attached directly to the benzene ring. It is a liquid and is somewhat soluble in water. Phenol is used in large quantities as an industrial chemical. It is produced almost entirely as an intermediate for the preparation of other chemicals. These include synthetic polymers such as phenolic resins, bis-phenol and caprolactam plastics intermediates, and chlorinated and alkylated phenols.

Phenol is used in the textile industry as a preservative in dyes and could be present in textile mill raw wastes in the 100 to 1,000 ug/l range according to the results of the DETO survey. Out of 418 questionnaire returns, 81 reported "known presence" and an additional 47 reported "suspected presence" in mill wastewaters. Reported sources cover a wide spectrum including the water supply; raw materials, including various fibers; dyes and dye carriers; finishing resins; nylon carpet processing; laboratory operations; and general cleaners and disinfectants used in the mill. In the field sampling program, phenol was detected at concentrations greater than 10 ug/l in the wastewaters from 25 of 44 mills, and at lesser concentrations at 4 additional mills.

Bis (2-ethylhexyl) Phthalate. Bis (2-ethylhexyl) phthalate belongs to the group of compounds known as phthalate esters. The phthalic acid esters (PAE) are a large group of substances widely used in the U.S. and the rest of the world as plasticizers. In the plastics industry, they are used to impart flexibility to plastic polymers, to improve workability during fabrication, and to extend or modify properties not present in the original plastic resins.

PAE are extensively used in polyvinylchloride plastics, which have a wide variety of applications. They are contained in building and construction materials (flooring, weatherstripping, wire, and cable), home furnishings (garden hoses, wall covering, upholstery), transportation materials (seat covers, auto mats), apparel (footwear, outerwear, baby pants), and food surfaces and medical products (food wrap film, medical tubing, intravenous bags). Dioctylphthalate (DOP) and its isomer di-2-ethylhexyl phthalate (DEPH) are probably the most widely used plasticizers today. PAE also have minor non-plastic uses as pesticide carriers, in cosmetics, fragrances, industrial oils, and insect repellents.

The PAE plasticizers, which can be present in concentrations up to 60 percent of the total weight of the plastic, are only loosely linked to the plastic polymers and are easily extracted. PAE are known to be widely distributed in the environment. They have been found in soil, water, air, fish tissue, and human tissue.

Bis(2-ethylhexyl) phthalate may make up from 10 to 50 percent of some coating formulations used in the textile industry. It was detected at levels of 10 ug/l or greater in wastewaters from 27 out of 44 (61%) mills in the field sampling program, although only 4 questionnaire returns out of 418 reported "suspected presence" in mill wastes. This toxic pollutant was also found at significant concentrations (10 ug/l or greater) in raw water supplies and in tubing blanks. This indicates that its use may be less widespread in the industry than the 61 percent occurrence noted above. It is clear, however, that in some mills this constituent is added to the waste stream during textile finishing.

Tetrachloroethylene. (Tetrachloroethylene, 1,1,2,2-tetrachloroethylene, perchloroethylene, PCE) is a colorless, nonflammable liquid used primarily as a solvent in dry cleaning industries. It is used to a lesser extent as a degreasing solvent in metal industries.

Perchloroethylene is widespread in the environment, and is found in water, aquatic organisms, air, foodstuffs, and human tissues, in quantities of micrograms per liter. The highest environmental levels of PCE are measured in commercial dry cleaning and metal degreasing industries.

Although PCE is released into water via aqueous effluents from production plants, consumer industries, and household sewage, its level in ambient water is reported to be minimal due to its high volatility.

Tetrachloroethylene is used in the textile industry as a dry cleaning solvent and in some dyeing operations as part of the carrier systems or scouring formulations. Out of 418 questionnaire returns, 29 indicated "known or suspected presence" in mill wastes. In the field sampling program of 44 mills, tetrachloroethylene was detected at levels greater than 10 ug/l at 4 mills, and at lower concentrations at 4 additional mills.

Toluene. Toluene is a clear, colorless, noncorrosive liquid with a sweet, pungent odor. The production of toluene in the U.S. has increased steadily since 1940 when approximately 117 million liters (31 million gallons) were produced; in 1970, production was 2.62 billion liters (694 million gallons). Approximately 70 percent of the toluene produced is converted to benzene, another 15 percent is used to produce chemicals, and the remainder is used as a solvent for paints and as a gasoline additive.

Toluene is a volatile compound and is readily transferred from water surfaces to the atmosphere. In the atmosphere, it is subject to photochemical degradation. It degrades to benzaldehyde and traces of peroxybenzoyl nitrate. Toluene can also re-enter the hydrosphere in rain.

Sources of toluene reported by the textile industry include dyes and dye carriers, raw materials, and use as a cleaning solvent. Toluene is one of 25 toxic pollutants that may be present in commercial dyes at levels less than 0.1 percent according to the survey carried out by DETO. Out of 418 questionnaire returns, 48 indicated "known or suspected presence" in mill wastewaters. In the field sampling program, toluene was detected at levels of 10 ug/l, or greater, at 18 of the 44 mills sampled, and at lesser concentrations at 13 additional mills.

Trichloroethylene. Trichloroethylene (1,1,2-trichloroethylene, TCE), a volatile nonflammable liquid, is used mostly in metal industries as a degreasing solvent. It had minor applications as a dry cleaning solvent and as an extractive solvent for decaffeinating coffee, but was replaced in both these capacities by perchloroethylene and methylene chloride, respectively.

Its volatilization during production and use is the major source of environmental levels of this compound. TCE has been detected in ambient air, in food, and in human tissue in ug/l (ppb) quantities. Its detection in rivers, municipal water supplies, the sea, and aquatic organisms indicates that TCE is widely distributed in the aquatic environment at the ug/kg level or lower. Trichloroethylene is not expected to persist in the environment. This is due in part to its short half-life in air and its evaporation from water.

Sources of trichloroethylene in textile mill wastewaters reported by the industry include its use as a solvent in dyeing and cleaning, and also in some raw materials. Out of 418 questionnaire returns, 21 indicated "known or suspected presence" in mill wastes. It was detected in the wastewaters at greater than 10 ug/l concentrations in 10 of the 44 mills visited in the field sampling program, plus three mills at lower concentrations.

Antimony. Antimony is a naturally occurring element that makes up between 0.2 and 0.5 ppm of the earth's crust. Environmental concentrations of antimony are reported at 0.33 ug/l in seawater of 35 parts per thousand salinity and at 1.1 ug/l in freshwater streams. Antimony and its compounds are used in the manufacturing of alloys, as flame retardants, pigments, and catalysts, as well as for medicinal and veterinary uses.

Individual mills reported possible sources of antimony in textile wastewaters as finishing agents, dyestuffs, and raw materials. The DETO survey results did not list antimony as one of the 25 toxic pollutants likely in the bulk of commercial dyes produced. Various antimony compounds have been used as mordants in dyeing, in printing pastes, and as pigments in dye manufacture. Antimony trioxide is used as a flame retarding agent. Out of 418 questionnaire returns, 52 indicated "known or suspected presence" in mill wastes. Of the 44 mills in the field sampling program, no antimony was detected in the wastewaters from roughly half. This metal was detected at concentrations judged to be above common background water supply levels (here selected as 20 ug/l for antimony) in eight mill waste streams. The water supplies of 12 mills were sampled and analyzed for antimony. One supply had a level of "less than 49 ug/l." The remaining 11 were all less than 18 ug/l.

Arsenic. Arsenic is a naturally occurring element often referred to as a metal, although chemically classified as a metalloid. Environmental concentrations of arsenic have been reported at 0.0005 percent in the earth's crust and 3 ug/l in sea water. Analyses of 1577 surface waters samples in the U.S. showed arsenic being present in 87 samples, with concentrations ranging from 5 to 336 ug/l, and a mean level of 64 ug/l (20). Arsenic and its compounds are used in the manufacturing of glass, cloth, and electrical semiconductors, as fungicides and wood preservatives, as growth stimulants for plants and animals, and in veterinary applications.

Individual textile mills reported likely sources of arsenic in their wastewaters as dyes and "raw materials." Out of 418 questionnaire returns, 16 indicated "known or suspected presence" in mill wastes. The survey carried out by DETO confirmed that some commercial dyes contain arsenic; likely levels are less than 0.1 percent. Other possible uses include its presence in fungicides and specialty chemicals. Arsenic was not detected at appreciable levels in any mill water supplies sampled. It was detected in approximately 25 percent of the raw waste and secondary effluent samples collected in the field sampling program. Its occurrence was less widespread than many of the other metallic toxic pollutants.

Cadmium. Cadmium is a soft, white metal that dissolves readily in mineral acids. Biologically, it is a non-essential element of high toxic potential. It occurs in nature chiefly as a sulfide salt, frequently in association with zinc and lead ores. Accumulations of cadmium in soils in the vicinity of mines and smelters may result in high local concentrations in nearby waters. The salts of the metal also may occur in wastes from electroplating plants, pigment works, and textile and chemical industries. Seepage of cadmium from electroplating plants has resulted in groundwater cadmium concentrations of 0.01 to 3.2 mg/l.

Dissolved cadmium was found in less than 3 percent of 1,577 U.S. surface water samples with a mean concentration of slightly under 10 ug/l. Most fresh waters contain less than 1 ug/l cadmium and most analyses of seawater indicate an average concentration of about 0.15 ug/l (20).

Sources of cadmium reported by individual textile mills include pigments, dyes, nylon carpet processing, and "raw materials", including dirt in raw wool. Cadmium was one of the toxic pollutants in the DETO survey that could be present in dyes at levels less than 0.1 percent. Of 418 questionnaire returns, 24 indicated "known presence" and 17 indicated "suspected presence" in mill wastes. In the field sampling program, cadmium was measured in only one of the 12 water supplies sampled. In two raw wastewater samples and in one secondary effluent sample, cadmium was measured at greater than 10 ug/l.

Chromium. Chromium salts are used extensively in the metal finishing industry as electroplating, cleaning, and passivating agents, and as mordants in the textile industry. They also are used in cooling waters in the leather tanning industry, in catalytic manufacture, in pigments and primer paints, and in fungicides and wood preservatives. In the analysis of 1,577 surface water samples collected at 130 sampling points in the U.S., chromium was found in 386 samples ranging from 1 to 112 ug/l; the mean concentration was 9.7 ug/l (20). Trivalent chromium is recognized as an essential trace element for humans. Hexavalent chromium in the workplace is suspected of carcinogenicity.

Sources of chromium reported by individual textile mills include dyes, mordants, pigments, other raw materials, and nylon carpet processing. In addition, chromium may result from plating baths used to resurface printing rolls and may also originate in blowdown from recirculating cooling systems where it is used to control biofouling. The results of the DETO survey confirmed that chromium may be present in some commercial premetallized dyes at levels of from 3 to 4 percent. The metal is an integral part of the dye molecule and most should exhaust onto the fiber being dyed. Of 418 questionnaire returns, 117 indicated "known presence" and an additional 55 indicated "suspected presence" in textile mill wastewaters. In the field sampling program, chromium was detected in only one of 12 water supply samples (at less than 4.6 ug/l). In the field sampling program, chromium was detected at all but 6 mills, with about two-thirds of the raw and secondary treated wastewaters having values less than 30 ug/l.

Copper. Copper is a soft heavy metal that is ubiquitous in its distribution in rocks and minerals of the earth's crust. In nature, copper occurs usually as sulfides and oxides and occasionally as metallic copper. Weathering and solution of these natural copper minerals result in background levels of copper in natural surface waters at concentrations generally well below 20 ug/l. Higher concentrations of copper are usually from anthropogenic sources. These sources include corrosion of brass and copper pipe by acidic waters, industrial effluents and fallout, sewage treatment plant effluents, and the use of copper compounds as aquatic algicides. Potential industrial copper pollution sources number in the tens of thousands in the U.S. However, the major industrial sources include the smelting and refining industries, copper wire mills, coal burning industries, and iron and steel producing industries. Copper may enter natural waters either directly from these sources or by atmospheric fallout of air pollutants produced by these industries.

A five year study of natural surface waters in the U.S. revealed copper concentrations ranging from less than 10 ug/l (the limit of detection) to 280 ug/l, with a mean value for U.S. waters of 15 ug/l. Values from 0.6 ug/l to 4.3 ug/l have been reported in seawater (20).

Sources of copper reported by individual textile mills include pigments, dyestuffs, and the mill plumbing system. The DETO survey results indicated that copper may be present in some commercial dyes at levels of 3 to 4 percent. Since the copper is an integral part of the dye molecule, most of it should be exhausted from the dye bath onto the fiber being dyed. Of 418 questionnaire returns, 87 indicated "known presence" and 79 indicated "suspected presence" in the mill wastewaters. In the field sampling program, copper was not detected in nine of the twelve water supply samples. Only one sample had more than 11 ug/l. Raw textile mill wastewaters measured in the field sampling program showed a wide range of values, with 19 samples having more than 50 ug/l, and 11 with more than 100 ug/l. The effluents from secondary mill treatment plants showed a wide range of values also, but there were fewer samples at the higher levels.

Cyanide. Cyanide compounds are almost universally present where life and industry are found. Besides being very important in a number of manufacturing processes, they are found in many plants and animals as metabolic intermediates that generally are not stored for long periods of time.

Possible sources of cyanide reported by individual textile mills include dyestuffs and "raw materials." The ATMI Task Group suggested that cyanide is probable in some waste streams, originating in laboratory and specialty chemicals. Cyanide was not among the 25 toxic pollutants identified in the DETO survey as possibly present in commercial dyes. Of 418 questionnaire returns, 16 indicated either "known or suspected presence" in mill wastewaters. In the field sampling program, cyanide was at less than 2 ug/l in 9 of the 12 water supply samples with the maximum level at 22 ug/l. In the raw wastewater samples, almost all were less than 10 ug/l with 3 in the 11 to 100 ug/l range. Similar results were obtained for the secondary effluent samples, although two samples contained more than 100 ug/l of cyanide.

Lead. Lead is a naturally occurring metal that makes up 0.002 percent of the earth's crust. The reported concentration of lead in seawater of 35 parts per thousand salinity is 0.03 ug/l, while available data indicate that the mean natural lead content of the world's lakes and rivers ranges from 1 to 10 ug/l. Analyses of over 1500 stream samples from 1962 to 1967 found lead in 19.3 percent of the samples, with concentrations ranging from 2 to 140 ug/l, and a mean value of 23 ug/l (20).

Lead is used in the metallurgy of steel and other metals; in ceramics, plastics and electronic devices; in construction materials and in x-ray and atomic radiation protection devices.

Sources of lead reported by individual textile mills include pigments, process chemicals, "raw materials", and tramp impurities in dyes. The DETO survey results indicated that lead may be present in some commercial dyes at levels less than 0.1 percent. Of 418 questionnaire returns, 34 indicated "known presence" and 27 indicated "suspected presence" in mill wastewaters. In the field sampling program, lead was either not detected or at less than 5 ug/l in 10 of the 12 water supply samples measured. Two samples had lead levels of 37 and 45 ug/l, respectively. In the raw textile mill samples analyzed, roughly 40 percent had lead levels below 10 ug/l, while 4 had levels above 100 ug/l. Of 16 secondary treatment effluents, 10 (60%) were below 10 ug/l, and only one sample had a concentration greater than 100 ug/l.

Mercury. Mercury, a silver-white metal that is a liquid at room temperature, can exist in three oxidation states: elemental, mercurous, and mercuric; it can be part of both inorganic and organic compounds.

A major use of mercury has been as a cathode in the electrolytic preparation of chlorine and caustic soda; this accounted for 33 percent of total demand in the U.S. in 1968. Electrical apparatus (lamps, arc rectifiers, and mercury battery cells) accounted for 27 percent, and industrial and control instruments (switches, thermometers, and barometers), and general laboratory applications accounted for 14 percent of demand. Use of mercury in antifouling and mildew-proofing paints (12 percent) and mercury formulations used to control fungal diseases of seeds, bulbs, plants, and vegetation (5 percent) were other major utilizations; however, mercury is no longer registered by the EPA for use in antifouling paints or for the control of fungal diseases of bulbs. The remainder (9 percent) was for dental amalgams, catalysts, pulp and paper manufacture, pharmaceuticals, and metallurgy and mining.

Sources of mercury reported by individual textile mills include pigments, dyes, and "raw materials", including impurities in caustic soda. The ATMI Task Group suggested that mercury is probably present in some textile mill wastewaters, originating in dyes and specialty chemicals.

The DETO survey results included mercury among the toxic pollutants possibly present in some commercial dyes at levels less than 0.1 percent. Of 418 questionnaire returns, 19 indicated "known presence" and 15 indicated "suspected presence" in mill wastewaters. In the field sampling program, mercury was detected in only 1 of the 12 water supplies sampled, at 0.79 ug/l. Of 51 raw textile mill wastewater samples, 11 had levels of 0.2 ug/l or greater, with only 2 of these above 1.0 ug/l. In effluents from secondary treatment plants at textile mills, there were 5 out of 38 samples with levels of 0.2 ug/l or above and none as high as 1.0 ug/l. Mercury is not commonly found in textile mill wastewaters.

Nickel. Nickel is a silver-white ductile metal commonly occurring in natural waters in the +2 valence state in concentrations ranging from a few micrograms per liter, to more than 100 ug/l. Nickel seldom is found in groundwater, and if present, probably exists in colloidol form.

Approximately 0.01 percent of the earth's crust is nickel, and it is ranked 24th in order of abundance of the elements. By far the greatest proportion of nickel in the earth's crust comes from igneous rocks. Some common minerals containing nickel include pentlandite and ullmannite. Certain secondary silicate minerals contain nickel, which also substitutes for magnesium in various primary minerals (e.g. olivine, hypersthene, hornblende, biotite).

In a study of 130 surface water sampling stations throughout the U.S., nickel appeared in 16.2 percent of 1,577 samples collected between 1962 and 1967, with a mean concentration of 19 ug/l and a range of 1 to 130 ug/l. In drinking water samples taken throughout the U.S., nickel was detected in only 4.6 percent of the samples, with a mean concentration of 34.2 ug/l and a range of 1 to 490 ug/l.

Sources of nickel reported by individual textile mills include pigments, dyes, processing chemicals, and "raw materials." The DETO survey confirmed that nickel may be present in some commercial dyes at levels less than 0.1 percent. Nickel may also originate from plating operations in resurfacing of printing rolls. Of 418 questionnaire survey returns, 28 indicated "known presence" and 23 indicated "suspected presence" in the mill wastewaters. In the field sampling program, nickel was measured at greater than 5 ug/l in 2 of the 12 water supplies sampled; one at 41 ug/l and the other at 47 ug/l. Of the raw wastewater samples, approximately 40 percent were less than 10 ug/l, with approximately 20 percent in each of the following ranges: 11 to 50 ug/l, 51 to 100 ug/l, and greater than 100 ug/l. The results for the secondary treatment effluents were similarly scattered, although the numbers of samples above 10 ug/l were reduced.

Selenium. Selenium is a naturally occurring element and is an essential waters, selenium levels are low (less than 1 ug/l) but in areas with seleniferous soils, water levels up to 300 ug/l have been reported (20).

The major source of selenium entering the environment is the weathering of selenium-containing soils and rocks. Man-related activities account for approximately 3,500 metric tons of selenium being discharged into the environment each year. Major uses include glass manufacturing, photocopying, electronic devices, pigments, and others including several veterinary uses.

No widely recognized sources of selenium in textile mill wastewaters were reported in this study. The ATMI Task Group suggested that selenium might be present in some dyes and speciality chemicals. This was not confirmed by the DETO survey of dye manufacturers. Of 418 questionnaire responses, 7 indicated "known presence" and 3 indicated "suspected presence" in the mill wastewaters, although no specific sources were mentioned. In the field sampling program, selenium was at undetectable levels in most water and wastewater samples. However, in two water supply samples and six raw and six secondary effluent samples, appreciable concentrations (from 11 to over 30 ug/l) were measured. The data developed in this study are insufficient to establish a possible link between water supply levels and wastewater concentrations. In summary, for most textile mills, selenium should not be a problem. For a few, in-plant controls or treatment may be required.

Silver. Silver is a white ductile metal occurring naturally in the pure form and in ores. Principal uses of silver are in photographic materials, as a conductor, in dental alloys, solder and braying alloys, paints, jewelry, silverware, and mirror production.

Of 418 questionnaire returns, 12 indicated "known presence" and 4 indicated "suspected presence" in textile mill wastewaters, although no specific sources were given. The ATMI Task Group suggested that silver was a probable constituent of some textile mill wastewaters, originating in dyes and/or specialty chemicals. The DETO survey did not confirm commercial dyes as a likely source of silver. In the field sampling program, silver was measured at greater than 5 ug/l in 2 of the 12 water supplies sampled, both at 17 ug/l. In 19 raw wastewater samples, silver was detected at greater than 10 ug/l, with 13 samples above 30 ug/l, and 1 above 100 ug/l. In secondary treatment effluents, there were eight with levels greater than 10 ug/l, six above 30 ug/l, and one above 100 ug/l. Based on these limited data, it seems that silver must be regarded as a constituent of the wastewaters from some textile mills.

Zinc. Zinc is a naturally occurring element that makes up approximately 0.02 percent of the earth's crust. It is used in various alloys, as a protective coating for other metals, in galvanizing sheet iron, and as a reducing agent. Zinc was detected in 1,207 of 1,577 surface water samples collected at 130 sampling locations throughout the U.S. between 1962 and 1967. The maximum observed concentration was 1,183 ug/l and the mean value was 64 ug/l. Levels of zinc in natural seawater approximate 5 ug/l (20).

Zinc originates from many sources in textile mill wastewaters, including pigments, dyes, dye stripping, coating materials, catalysts, latex curing, and in many specialty chemicals both as an added component and as an impurity. The DETO survey pointed out that some dyes are prepared as double salts of zinc and may contain up to 3 percent of this metal. Unlike chromium and copper, the zinc is not exhausted onto the fiber in dyeing. Zinc can also be contributed by water conditioning chemicals, alloys used in pumps and valves, galvanized metals, painted surfaces, and several other sources in industrial facilities. Of 418 questionnaire returns, 100 indicated "known presence" and 64 indicated "suspected presence" in the mill wastewaters. In the field sampling program, zinc in the 12 water supply samples ranged from 10 to 4500 ug/l. Four had levels above 100, and two were above 1000. For some mills, the water supply must be considered in undertaking a program to control the discharge of zinc. The levels measured in raw and treated mill wastewaters were roughly equivalent with about 37 percent of the samples less than 100 ug/l, 39 percent in the 100 to 500 ug/l range, 11 percent in the 500 to 1000 ug/l range, and the remaining 13 percent above 1000 ug/l, including 3 percent over 5000 ug/l.

Group 2A - Potentially Significant in Textile Wastewaters: Detected More Than Once

Group 2 comprises three subgroups, based on frequency of detection in the field sampling program and information from the special industrial toxic pollutant committees.

The toxic pollutants detected in the raw or treated wastewater from at least two mills in the field sampling program, but at less than 10 ug/l in secondary treatment effluents, are the following:

1. acenaphthene
7. chlorobenzene
9. hexachlorobenzene
11. 1,1,1-trichloroethane
27. 1,4-dichlorobenzene
31. 2,4-dichlorophenol
44. methylene chloride
62. N-nitrosodiphenylamine
67. butyl benzyl phthalate
68. di-n-butyl phthalate
70. diethyl phthalate
71. dimethyl phthalate
78. anthracene
84. pyrene
127. thallium (10 ug/l limit exceeded)

Acenaphthene. Acenaphthene (1,2-dehydro-acenaphthylene or 1,8-ethylenenaphthylene) occurs in coal tar produced during the high temperature carbonization or coking of coal. Laboratory experimentation points out the possibility of limited metabolism of acenaphthene to naphthalic acid and naphthalic anhydride. Acenaphthene is used as a dye intermediate in the manufacture of some plastics, as an insecticide, and as a fungicide.

The DETO survey results indicate that acenaphthene may be present in some commercial dyes at concentrations less than 0.1 percent. Out of 418 questionnaire returns, 7 indicated "suspected presence" in the mill wastewaters with 1 respondent citing "raw materials" as the source. This pollutant was detected in the raw wastes of three mills with a maximum level of 12 ug/l. It was also detected in treated effluents at two additional mills where it was not detected in the raw wastes at the time of sampling. In a secondary effluent, the level was 0.5 ug/l, and in a polishing pond effluent, it was 2.0 ug/l. In no case was acenaphthene detected in both the raw wastes and the treated effluent at the same mill in the field sampling program.

Chlorobenzene. The compound chlorobenzene (also referred to as monochlorobenzene) is a chlorinated benzene and is one of a class of aromatic organic compounds characterized by the substitution of from one to six chlorine atoms on the benzene nucleus. The compound has seen use in the synthesis of ortho- and para-nitrochlorobenzenes, as a solvent, in phenol manufacturing, and in the manufacture of DDT. During the period 1973-1974, production and use of monochlorobenzene resulted in approximately 34,278 metric tons entering the aquatic environment, approximately 690 metric tons ending up as solid waste, and 362 metric tons entering the atmosphere.

Chlorobenzene is used as a carrier in some textile dyeing systems. The DETO survey results indicated that it may be present in some commercial dyes at concentrations less than 0.1 percent. Out of 418 questionnaire returns, 4 mills indicated "known presence" and 28 indicated "suspected presence" in the mill wastes. In the field sampling program, chlorobenzene was detected in the raw wastewaters of 5 mills with concentrations ranging from less than 5 up to almost 300 ug/l. It was detected only once in a secondary effluent sample and at 3.5 ug/l. It was not detected in the raw waste at this mill at the time of sampling.

Hexachlorobenzene. The compound hexachlorobenzene is a chlorinated benzene and is one of a class of aromatic organic compounds characterized by the substitution of from one to six chlorine atoms on the benzene nucleus. The compound has seen use as a fungicide to control wheat bunt and smut on seed grains, in the manufacture of dyes, as an intermediate in organic synthesis, as a porosity controller in the manufacture of electrodes, as a wood preservative, and as an additive in pyrotechnic compositions for the military. In 1973, approximately 318 metric tons was produced in the U.S.

No very obvious sources of hexachlorobenzene in textile mill wastewaters were found in this study. Individuals speculated that it may originate as a trace ingredient or impurity in some dye carriers or specialty chemicals and may be a fungicidal component of some industrial cleaning compounds. Out of 418 questionnaire returns, 1 indicated "known presence" and 5 indicated "suspected presence," but no sources were suggested. This toxic pollutant was detected in the wastewaters of 5 mills in the field sampling program. Two raw water samples had levels of 0.5 and 2.0 ug/l. An intermediate-level effluent had 0.5 ug/l, while it was not detected in any secondary effluent samples. It was detected in two polishing pond effluents at levels of 0.3 and 0.8 ug/l. At none of the mills was it detected in both raw and treated waste samples.

1,1,1-Trichloroethane. The compound 1,1,1-trichloroethane belongs to the chemical class known as chlorinated ethanes. The chlorinated ethanes, which are produced in relatively large quantities, are used for the production of tetraethyl lead and vinyl chloride, as industrial solvents, and as intermediates in the production of other organochlorine compounds. Chlorinated ethanes have been found in drinking waters, in natural waters, and in aquatic organisms and foodstuffs.

1,1,1-Trichloroethane is reported to be used in some textile mills as a carrier, a scouring solvent, and a cleaning agent. Out of 418 questionnaire returns, 5 indicated "known presence" and 34 indicated "suspected presence" in mill wastes. In the field sampling program, it was detected in the raw wastes of 4 mills with a maximum concentration of 17 ug/l. In three of the mills, it was not detected in the secondary treated effluent. In the fourth mill, this compound was detected after both secondary and "tertiary" treatment, although at levels of "less than 5 ug/l."

1,4-Dichlorobenzene. The compound 1,4-dichlorobenzene belongs to the chemical class known as dichlorobenzenes. This class of compounds is represented by three isomers: 1,2-dichloro, 1,3-dichloro, and 1,4-dichlorobenzene. Both 1,2-dichloro and 1,4-dichlorobenzene are produced almost entirely as byproducts from the production of monochlorobenzene. Production in 1975 consisted of 24,801 metric tons of 1,2-dichlorobenzene and 20,754 metric tons of 1,4-dichlorobenzene. The estimated losses of dichlorobenzenes during the production of monochlorobenzene are 20.5 kg/metric ton to wastewater and 22.2 kg/metric ton to land disposal. Because 1,4-dichlorobenzene sublimes at room temperature, this compound probably enters the atmosphere in large quantities.

The major uses of 1,4-dichlorobenzene are as a process solvent in the manufacturing of toluene diisocyanate, and as an intermediate in the synthesis of dyestuffs, herbicides, and degreasers. The bulk of 1,4-dichlorobenzene usage (90 percent of the total consumption) is in direct application as air deodorants and insecticides.

1,4-Dichlorobenzene is used for moth proofing of textiles, and may possibly be an ingredient or impurity in some dye carriers, possibly some of those used with polyesters. Out of 418 questionnaire returns, 2 indicated "known presence" and 8 indicated "suspected presence" in mill wastes. In the field sampling program, this toxic pollutant was detected in samples from three mills. Raw wastewater samples contained concentrations of 6.5 and 215 ug/l, and secondary effluent samples contained 0.2 and 1.5 ug/l. One raw and one treated effluent sample had no detectable concentrations of this compound.

<u>2,4-Dichlorophenol</u>. The compound 2,4-dichlorophenol (DCP) is a commercially produced substituted phenol used entirely in the manufacture of industrial and agricultural products. These products include herbicides, germicides, temporary soil sterilants, plant growth regulators, mothproofing agents, seed disinfectants, miticides, and wood preservatives.

There were no sources for 2,4-dichlorophenol in textile mill wastewaters cited or suggested by any industry representatives or questionnaire respondents. Out of 418 questionnaire returns, 2 indicated "suspected presence" in mill wastes. In the field sampling program it was detected in the raw wastewaters of two mills at levels of 41 and less than 10 ug/l. At a third mill it was detected in the effluent from a polishing pond at 0.5 ug/l. It was not found in any secondary effluents.

<u>Methylene Chloride</u>. Methylene chloride belongs to the class of compounds known as halomethanes, which are a subcategory of halogenated hydrocarbons. It has been referred to as dichloromethane, methylene dichloride, and methylene bichloride. It is a common industrial solvent found in insecticides, metal cleaners, paints, and paint and varnish removers.

Methylene chloride is used to extract certain fractions of toxic pollutants from wastewaters in the EPA analytical protocol. It was reported that some samples collected in the field sampling program were found to have unusually high concentrations of methylene chloride and these results were discarded because they were unreasonable and contamination of the samples while in the analytical laboratory was suspected. Measures to prevent such contamination have been taken. This toxic pollutant is a solvent and finds use in textile mills in dyeing and laboratory operations and as a component of some coatings, degreasing compounds, spot removers, and machine oils. Out of 418 questionnaire returns, 3 indicated "known presence" and 17 indicated "suspected presence" in the mill wastes. In the field sampling program, it was detected in the raw wastewaters from three mills, ranging from less than 5 to 100 ug/l. Secondary treatment effluent levels at these mills were all below 5 ug/l. At three additional mills, it was found in treated effluents, but not in the corresponding raw waste samples. The level in one secondary effluent sample was less than 5 ug/l, and the levels in two polishing pond effluents were 10 and 48 ug/l.

N-nitrosodiphenylamine. The compound N-nitrosodiphenylamine belongs to the chemical class known as nitrosamines. The organic nitroso-compounds are a large group of chemicals characterized by a nitroso group (N=O) that is attached to the nitrogen of a secondary amine.

Patent applications show potential uses of nitrosamines in the manufacture of rubber, dyestuff, gasoline additives, lubricating oils, explosives, insecticides, fungicides, dielectric fluids, acrylonitrile, plasticizers, industrial solvents, and hydrazine. At present, two major industries are involved in handling nitrosamines: organic chemicals manufacturing and rubber processing. Diphenylnitrosamine is the only nitrosamine that is produced in quantities greater than 450 kg. It is used in pesticides and as a vulcanizing retarder in rubber processing. Other nitrosamines are not produced commercially except as research chemicals.

N-nitrosodiphenylamine may be a contaminant of some dyes, although such was not indicated in the DETO survey. Out of 418 questionnaire returns, 4 indicated "suspected presence" in the mill waste, but no possible sources were suggested. In the field sampling program, this toxic pollutant was detected in the raw wastewaters of three mills at levels ranging from less than 10 to 72 ug/l. It was not detected in treated effluents at any of these mills.

Butyl Benzyl Phthalate. Butyl benzyl phthalate belongs to the group of compounds known as phthalate esters. The phthalic acid esters (PAE) are a large group of substances widely used in the U.S. and the rest of the world as plasticizers. In the plastics industry, they are used to impart flexibility to plastic polymers, improve workability during fabrication, and extend or modify properties not present in the original plastic resins.

PAE are extensively used in polyvinylchloride plastics, which have a wide variety of applications. They are contained in building and construction materials (flooring, weatherstripping, wire and cable), home furnishings (garden hoses, wall covering, upholstery), transportation materials (seat covers, auto mats), apparel (footwear, outerwear, baby pants), and food surfaces and medical products (food wrap film, medical tubing, intravenous bags). Dioctylphthalate (DOP) and its isomer di-2-ethylhexyl phthalate (DEHP) are probably the most widely used plasticizers today. PAE also have minor non-plastic uses as pesticide carriers, in cosmetics, fragrances, industrial oils, and insect repellents.

The PAE plasticizers, which can be present in concentrations up to 60 percent of the total weight of the plastic, are only loosely linked to the plastic polymers and are easily extracted. PAE are known to be widely distributed in the environment. They have been found in soil, water, air, fish tissue, and human tissue.

Butyl benzyl phthalate is reported to be used in the textile industry as a plasticizer for polyvinyl and cellulosic resins. Out of 418 questionnaire returns, 3 indicated "known presence" and 2 indicated "suspected presence" in the mill waste, with sources cited as dyestuff, dye carrier, and a resin. DETO suggests that phthalates may be present as anti-dusting agents in dyes. In the field sampling program it was detected in the raw wastewater samples at two mills at 10 and 73 ug/l. These mills were indirect dischargers, and provided no significant pretreatment prior to discharge to the POTW.

Di-n-butyl Phthalate. Di-n-butyl phthalate belongs to the group of compounds known as phthalate esters. The phthalic acid esters (PAE) are a large group of substances widely used in the U.S. and the rest of the world as plasticizers. In the plastics industry, they are used to impart flexibility to plastic polymers, improve workability during fabrication, and extend or modify properties not present in the original plastic resins.

PAE are extensively used in polyvinylchloride plastics, which have a wide variety of applications. They are contained in building and construction materials (flooring, weatherstripping, wire and cable), home furnishings (garden hoses, wall covering, upholstery), transportation materials (seat covers, auto mats), apparel (footwear, outerwear, baby pants), and food surfaces and medical products (food wrap film, medical tubing, intravenous bags). Dioctylphalate (DOP) and its isomer di-2-ethylhexyl phthalate (DEHP) are probably the most widely used plasticizers today. PAE also have minor non-plastic uses as pesticide carriers, in cosmetics, fragrances, industrial oils, and insect repellents.

The PAE plasticizers, which can be present in concentrations up to 60 percent of the total weight of the plastic, are only loosely linked to the plastic polymers and are easily extracted. PAE are known to be widely distributed in the environment. The have been found in soil, water, air, fish tissue, and human tissue.

Di-n-butyl phthalate is reported to be used in the textile industry as a plasticizer and resin solvent and may also find use as a textile lubricating agent. It was also suggested that it may be an ingredient of some dye carriers, specialty machine oils, insecticides, and, as a remote possibility, in some dyes as an anti-dusting agent. Out of 418 questionnaire returns, 1 indicated "known presence" and 6 indicated "suspected presence" in the mill wastes, but no specific sources were suggested. In the field sampling program, di-n-butyl phthalate was detected in the raw wastewaters of seven mills at levels ranging from below 10 to 67 ug/l. It was found in only one secondary effluent sample, at 3.6 ug/l. At three mills where it was not detected in the raw wastes, it was found in treatment pond effluents at levels ranging from 5 to 58 ug/l. These mills did not provide conventional secondary treatment. Concentrations ranging up to 3.7 ug/l were found in 6 water supply and tubing blank samples.

<u>Diethyl Phthalate</u>. Diethyl phthalate belongs to the group of compounds known as phthalate esters. The phthalic acid esters (PAE) are a large group of substances widely used in the U.S. and the rest of the world as plasticizers. In the plastics industry, they are used to impart flexibility to plastic polymers, improve workability during fabrication, and extend or modify properties not present in the original plastic resins.

PAE are extensively used in polyvinylchloride plastics, which have a wide variety of applications. They are contained in building and construction materials (flooring, weatherstripping, wire and cable), home furnishings (garden hoses, wall covering, upholstery), transportation materials (seat covers, auto mats), apparel (footwear, outerwear, baby pants), and food surfaces and medical products (food wrap film, medical tubing, intravenous bags). Dioctylphthalate (DOP) and its isomer di-2-ethylhexyl phthalate (DEHP) are probably the most widely used plasticizers today. PAE also have minor non-plastic uses a pesticide carriers, in cosmetics, fragrances, industrial oils, and insect repellents.

The PAE plasticizers, which can be present in concentrations up to 60 percent of the total weight of the plastic, are only loosely linked to the plastic polymers and are easily extracted. PAE are known to be widely distributed in the environment. They have been found in soil, water, air, fish tissue, and human tissue.

Diethyl phthalate may reportedly originate in uses as a plasticizer and as a component of dye carrier systems, specialty machine oils, and lubricants in the textile industry. DETO suggests that it may be present as an anti-dusting agent in some dyes. Out of 418 questionnaire returns, 7 indicated "suspected presence" in the mill wastes, but no sources were suggested. In the field sampling program, this toxic pollutant was detected in the wastewaters of 17 mills, although only once was it found in both the raw wastes and secondary treated effluents of a mill. It was found in the raw wastewaters of 10 mills with most values below 10 ug/l and three mills at 34, 69, and 86 ug/l. It was found in four secondary effluent samples at concentrations ranging from 0.5 to 9.4 ug/l; in two polishing pond effluents at 2.6 and 11 ug/l; and in two pilot plant tertiary treatment effluents at 3.2 and 12 ug/l. It was detected in 5 water supply and tubing blank samples at levels from 0.4 to 5.5 ug/l.

Dimethyl Phthalate. Dimethyl phthalate belongs to the group of compounds known as phthalate esters. The phthalic acid esters (PAE) are a large group of substances widely used in the U.S. and the rest of the world as plasticizers. In the plastics industry, they are used to impart flexibility to plastic polymers, improve workability during fabrication, and extend or modify properties not present in the original plastic resins.

PAE are extensively used in polyvinylchloride plastics, which have a wide variety of applications. They are contained in building and construction materials (flooring, weatherstripping, wire and cable), home furnishings (garden hoses, wall covering, upholstery), transportation materials (seat covers, auto mats), apparel (footwear, outerwear, baby pants), and food surfaces and medical products (food wrap film, medical tubing, intravenous bags). Dioctylphthalate (DOP) and its isomer di-2-ethylhexyl phthalate (DEHP) are probably the most widely used plasticizers today. PAE also have minor non-plastic uses as pesticide carriers, in cosmetics, fragrances, industrial oils, and insect repellents.

The PAE plasticizers, which can be present in concentrations up to 60 percent of the total weight of the plastic, are only loosely linked to the plastic polymers and are easily extracted. PAE are known to be widely distributed in the environment. They have been found in soil, water, air, fish tissue, and human tissue.

Reported sources of dimethyl phthalate in textile mill wastewaters were very limited. DETO suggests that it may be present as an anti-dusting agent in some dyes. Two questionnaire respondents indicated its use as an antimigrant in dyeing and as a component of a proprietary chemical. Despite this limited response, out of 418 returns, 8 indicated "known presence" and 17 indicated "suspected presence" in the mill wastes. In the field sampling program, it was detected in the raw wastes of four mills at levels ranging from 12 to 14 ug/l. It was not detected in the secondary effluents at these mills. At another mill it was found only in the secondary effluent, at a level of 1.0 ug/l.

Anthracene. Anthracene belongs to the chemical class of compounds known as polynuclear aromatic hydrocarbons (PAH's). PAH's are formed as a result of combustion of organic compounds without sufficient oxygen.

This leads to the formation of C-H free radicals that can polymerize to form various PAH's. Domestic and industrial soots, coal tar, and pitch are the products of incomplete combustion of carbonaceous materials such as wood, coal, and oil. Naturally formed shale oil and petroleum contain PAH.

The DETO survey results indicate that anthracene may be present in some commercial dyes at concentrations less than 0.1 percent. Out of 418 questionnaire returns, 2 indicated "known presence" and 8 indicated "suspected presence" in the mill wastes, with direct dyes cited as sources in two cases. Anthracene was detected in the wastewaters at two mills in the field sampling program; one raw waste sample at 0.1 ug/l, and one secondary treatment effluent sample at 4.4 ug/l. Interestingly, it was detected in 10 water supply and blank samples at concentrations ranging up to 0.6 ug/l.

Pyrene. Pyrene belongs to the chemical class of compounds known as polynuclear aromatic hydrocarbons (PAH's). PAH's are formed as a result of combustion of organic compounds without sufficient oxygen. This leads to the formation of C-H free radicals that can polymerize to form various PAH's. Domestic and industrial soots, coal tar, and pitch are the products of incomplete combustion of carbonaceous materials such as wood, coal, and oil. Naturally formed shale oil and petroleum contain PAH.

The literature cites pyrene usage as a dye intermediate, but this was not indicated by the DETO survey. No sources were suggested by the textile industry representatives, other than its use in fire extinguishers. Of 418 questionnaire returns, 2 indicated "suspected presence" in the mill wastes, but without suggesting possible sources. In the field sampling program, it was found in the wastewaters of four mills. At one, the raw waste sample contained 0.9 ug/l and the secondary effluent, 0.2 ug/l. At the other mills it was not detected in the raw wastes, but secondary sample concentrations of 0.1 to 0.3 ug/l were detected. It was not detected in any water supply or blank samples.

Thallium. Thallium is a silver-white metal that constitutes about 0.003 percent of the earth's crust. The average concentration of thallium in seawater is reported to be 10 mg/l, while analyses of U.S. river water during 1958 and 1959 detected no thallium.

Industrial uses of thallium include the manufacture of alloys, electronic devices, and special glass. Many thallium-containing catalysts have been patented for industrial organic reactions.

No specific sources of thallium peculiar to textile mill operations were cited by industry representatives. It was speculated that it might be found as "residue from catalyst or rodenticide." Out of 418 questionnaire responses, 2 indicated "known presence" and 1 indicated "suspected presence" in the mill wastes, with no potential sources suggested. In the field sampling program, thallium was detected in raw wastewater samples from two mills at levels of "less than 5 ug/l" and 9 ug/l. It was not detected in the secondary treated effluent of the first of these mills, but levels up to 18 ug/l were detected in the secondary effluent of the second mill. One laboratory reported "less than 3 ug/l" for several samples. This is regarded here as virtually equivalent to "not detected." The other analytical laboratory, using a minimum detection limit of 0.05 ug/l, did not detect any thallium in 73 textile mill wastewater samples.

Group 2B - Potentially Significant in Textile Wastewaters: Detected Only Once

The toxic pollutants detected in the raw or treated wastewaters at only one mill and at less than 10 ug/l in secondary treatment effluents or established as potentially present in textile effluents by industrial reference sources (DETO or ATMI) are the following:

5. benzidine
10. *1,2-dichloroethane
13. *1,1-dichloroethane
20. *2-chloronaphthalene
24. *2-chlorophenol
28. 3,3-dichlorobenzidine
29. *1,1-dichloroethylene
32. *1,2-dichloropropane
34. *2,4-dimethylphenol
36. *2,6-dinitrotoluene
37. *1,2-diphenylhydrazine
45. *methyl chloride
46. methyl bromide
48. *dichlorobromomethane
57. *2-nitrophenol
58. *4-nitrophenol
59. 2,4-dinitrophenol
61. N-nitrosodimethylamine
74. *3,4-benzofluoranthene
75. *11,12-benzofluoranthene
80. *fluorene
81. phenanthrene
88. *vinyl chloride
90. *dieldrin
92. *4,4'-DDT
117. *beryllium

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* Detected at one mill

Benzidine. Benzidine (4,4'-diaminobiphenyl) is an aromatic amine. This grayish, crystalline, slightly water-soluble compound is usually derived from nitrobenzene. It is reported used in the manufacture of dyes, especially Congo Red.

The DETO survey results indicated that benzidine may be present in some commercial dyes at concentrations less than 0.1 percent. DETO also noted that such dyes are being rapidly phased out of production. Out of 418 questionnaire returns, 6 indicated "known presence" and 42 indicated "suspected presence" in the mill wastes, with dyes cited as the probable source in all cases. This toxic pollutant was not detected in any samples in the field sampling program.

1,2-Dichloroethane. The compound 1,2-dichloroethane (ethylene dichloride) belongs to the chemical class known as chlorinated ethanes. The compounds in this class are produced in large quantities and used for the production of tetraethyl lead and vinyl chloride, as industrial solvents, and as intermediates in the production of other organochlorine compounds. Some have been found in drinking waters, in natural waters, and in aquatic organisms and foodstuffs.

No particular usage of 1,2-dichloroethane in textile mills was cited by representatives of the textile or dyestuff manufacturing industries, although it was speculated that it might be used as a spot remover and as a solvent in some epoxy formulations. Out of 418 questionnaire returns, 1 indicated "known presence" and 6 indicated "suspected presence" in mill wastes, with one respondent suggesting dyes and chemicals as the source. This compound was detected at one mill in the field sampling program; at "less than 5 ug/l" in the raw wastewater, at 5.8 ug/l in the effluent from an experimental DAF unit, and it was not detected in the secondary effluent.

1,1-Dichloroethane. The compound 1,1-dichloroethane belongs to the chemical class known as chlorinated ethanes. The chlorinated ethanes, which are produced in large quantities, are used for the production of tetraethyl lead and vinyl chloride, as industrial solvents, and as intermediates in the production of other organochlorine compounds. Some have been found in drinking waters, in natural waters, and in aquatic organisms and foodstuffs.

There were no sources in textile mill wastewaters for 1,1-dichloroethane cited or suggested by industry representatives. Out of 418 questionnaire returns, 1 indicated "known presence" and 1 indicated "suspected presence" in the mill waste. In the field sampling program, it was detected in two raw wastewater samples collected on consecutive days at one wool scouring mill at concentrations of 12 to 14 ug/l. It was not detected in the secondary effluent.

2-Chloronaphthalene. The compound 2-chloronaphthalene belongs to the chemical class known as chlorinated naphthalenes. These compounds consist of the naphthalene double ring where any or all of the eight hydrogen atoms can be replaced with chlorine. The commercial products are usually mixtures with various degrees of chlorination; they are presently marketed as halowaxes.

Tri- and tetra-chloronaphthalenes (solids) comprise the bulk of market use as the paper impregnant in automobile capacitors. Lesser use is made of the mono- and di-chloronaphthalenes as oil additives for engine cleaning, and in fabric dyeing. Possible impurities of these products are chlorinated derivatives, corresponding to the impurities in coal tar, or petroleum-derived naphthalene feedstock which may include biphenyls, fluorenes, pyrenes, anthracenes, and dibenzofurans.

The potential for environmental exposure may be significant when these compounds are used as oil additives in electroplating, and in fabric dyeing. The extent of leaching of chlorinated naphthalenes from discarded capacitors and old cable insulation (manufactured prior to curtailment of the chemical's use in such products) has not been determined.

No sources for 2-chloronaphthalene were cited or suggested in textile mill wastewaters by either textile or dye manufacturing industry representatives. Out of 418 questionnaire returns, 3 indicated "known presence" and 2 indicated "suspected presence" in the mill waste, with one respondent each citing reactive and direct dyes as the probable source. This toxic pollutant was detected once at "less than 10 ug/l" in a raw wastewater sample. It was not detected in the secondary effluent sample.

2-Chlorophenol. The compound 2-chlorophenol is a commercially produced chemical used entirely as an intermediate in the production of other chemicals. It represents a basic chemical feedstock for the manufacture of higher chlorophenols for such uses as fungicides, slimicides, bactericides, antiseptics, disinfectants, and wood and glue preservatives. The compound is also used to form intermediates in the production of phenolic resins and has been utilized in a process for extracting sulfur and nitrogen compounds from coal.

The only suggested source of 2-chlorophenol in textile mill wastewaters was as a constituent or impurity in dyes. This was not confirmed by the DETO survey. Out of 418 questionnaire responses, 1 indicated "known presence" and 8 indicated "suspected presence" in the mill waste, with "dye and chemicals" cited as the probable source by one respondent. This toxic pollutant was found at one mill in the field sampling program; at 73 ug/l in the raw wastewater, and 5.9 ug/l in the secondary treated effluent.

3,3-Dichlorobenzidine. Dichlorobenzidine is used in the production of dyes and pigments and as a curing agent for polyurethanes. This compound is soluble in organic solvents, but it is nearly insoluble in water.

The ATMI Task Force suggested that 3,3-dichlorobenzidine might be present in textile mill wastewaters as a trace impurity in some dyes, perhaps azo dyes. This was not confirmed by the DETO survey results. Out of 418 questionnaire returns, 1 indicated "known presence" and 10 indicated "suspected presence" in the mill waste, with no probable sources suggested. This pollutant was not detected in any samples in the field sampling program.

<u>1,1-Dichloroethylene</u>. The dichloroethylenes are 1,1-dichloroethylene, (vinylidene chloride, 1,1-DCE), cis 1,2-dichloroethylene, and trans 1,2-dichloroethylene. Presently, only 1,1-dichloroethylene has commercial or practical use because neither isomer of 1,2-dichloroethylene has developed wide industrial use as a solvent or chemical intermediate.

1,1-dichloroethylene is used in the synthesis of methylchloroform and in the production of polyvinylidene chloride copolymers (PVDC). Among the monomers used in copolymer production are vinyl chloride, acrylonitrile, and alkyl acrylates. The impermeability of PVDC make them useful, primarily as barrier coatings in the packaging industry. Polymers with high 1,1-dichloroethylene content (Saran) are widely used in the food packaging industry. The heat-seal characteristics of Saran coatings make them useful in the manufacture of nonflammable synthetic fiber. 1,1-dichloroethylene polymers have also been used extensively as interior coatings for ship-tanks, railroad cars and fuel storage tanks, and for coating of steel pipes and structures.

No possible sources of 1,1-dichloroethylene in textile mill wastewaters were found in this study. No questionnaire returns indicated either "known" or "suspected presence." This toxic pollutant was found in one raw wastewater sample at one mill at "less than 5 ug/l." It was not detected in the secondary effluent samples at this mill.

<u>1,2-Dichloropropane</u>. Principal uses of dichloropropanes are as soil fumigants for the control of nematodes, in oil and fat solvents, and in dry cleaning and degreasing processes. The presence of these compounds in water can result from agricultural runoff and industrial and municipal effluents. Dichloropropanes were detected in New Orleans drinking water.

No specific sources of 1,2-dichloropropane in textile mill wastewaters were found in this study. This solvent is mentioned in the general chemical literature as a cleaning and degreasing agent, but textile manufacturing is not cited as an area of use. None of the 418 questionnaire returns indicated either "known" or "suspected presence" in the mill waste. In the field sampling program, this toxic pollutant was found at one mill in the raw wastewater samples on consecutive days at levels of 100 and 36 ug/l. It was not detected in the secondary treated effluent.

2,4-Dimethylphenol. The compound 2,4-dimethylphenol (2,4-DMP) is derived from coal and petroleum sources. It finds use commercially as an important chemical feedstock or constituent for the manufacture of a wide range of commercial products for industry and agriculture.

Textile industry representatives suggested that possible sources of 2,4-dimethylphenol in textile mill wastewaters were its use as solvent, plasticizer, additive to lubricants, component of carrier sytems, and insecticide and fungicide. Out of 418 questionnaire returns, 2 indicated "suspected presence" in the mill waste, without citing possible sources. In the field sampling program, this pollutant was detected in the wastewaters at two mills. It was not found in the raw wastes, but was in one secondary effluent sample at 8 ug/l and in one polishing pond effluent sample at 9 ug/l.

2,6-Dinitrotoluene. Dinitrotoluene (DNT) is an ingredient of explosives for commercial and military use and is used as a chemical stabilizer in the manufacture of smokeless powder. In 1975, the production of 2,4-and 2,6-DNT in the U.S. was 264,030 metric tons. The production of DNT is expected to increase yearly at a rate of 20 to 25 percent.

Possible sources of 2,6-dinitrotoluene in textile mill wastewaters suggested by industry include trace levels in some dyes and in dye testing, although these were not regarded as very common sources in the industry. The DETO survey results did not confirm its likely presence in dyes. Out of 418 questionnaire returns, 3 indicated "suspected presence" in the mill waste. In the field sampling program, this pollutant was detected in one raw wastewater sample, at 54 ug/l. It was not found in the pond treated effluent at this mill.

1,2-Diphenylhydrazine. Diphenylhydrazine exists in two structural forms: 1,1-diphenylhydrazine and 1,2-diphenylhydrazine. 1,2-Diphenlhydrazine (hydrazobenzene) is insoluble in water; in air, it will oxidize to form azobenzene, a compound with slight water solubility. When reacted with HCl or H2SO4, hydrazobenzene will form benzidine.

The ATMI Task Force suggested that 1,2-diphenylhydrazine might find limited use in textile mill laboratories and might be an impurity in azo dyes. This latter use was not confirmed by the DETO survey. Out of 418 questionnaire returns, 5 indicated "suspected presence" in the mill waste, with no possible sources suggested. This compound was found in one of two raw wastewater samples at one mill at 22 ug/l. It was not found in the secondary treated effluent samples.

Methyl Chloride. Methyl chloride belongs to the class of compounds known as halomethanes, which are a subcategory of halogenated hydrocarbons. Methyl chloride is also known as chloromethane. It is a colorless, flammable, almost odorless gas at room temperature and pressure. It is used as a refrigerant, a methylating agent, a dewaxing agent, and a catalyst solvent in synthetic rubber production.

The ATMI Task Force suggested that methyl chloride might be used as an aerosol propellant. Out of 418 questionnaire returns, 1 indicated "known presence" and 2 indicated "suspected presence" in the mill waste. One respondent cited laboratory and dyeing as sources, and another reported intermittent use as a scouring chemical. In the field sampling program, this volatile compound was detected in one of two raw wastewater samples at one mill at "less than 5 ug/l." It was not found in the two secondary effluent samples at this mill.

Methyl Bromide. Methyl bromide belongs to the class of compounds known as halomethanes, which are a subcategory of halogenated hydrocarbons. Methyl bromide has been referred to as bromomethane, monobromomethane, and embafume. It has been widely used as a fumigant, fire extinguisher, refrigerant, and insecticide. Today the major use of methyl bromide is as a fumigating agent.

The DETO survey results indicate that methyl bromide may be present in some commercial dyes at less than 0.1 percent. No other likely sources in textile mill wastewaters were found in this study. Of 418 questionnaire returns, 4 indicated "suspected presence" in the mill waste. No sources were suggested. This toxic pollutant was not detected in any wastewater samples in the field sampling program.

Dichlorobromomethane. Dichlorobromomethane belongs to the class of compounds known as halomethanes, which are a subcategory of halogenated hydrocarbons. Specific industrial uses are not known.

No sources of dichlorobromomethane in textile mill wastewaters were uncovered in this study. Out of 418 questionnaire returns, none indicated either "known" or suspected presence" in the mill waste. In the field sampling program, this compound was found in one of two raw wastewater samples at one mill at 6.6 ug/l. It was not found in the two secondary effluent samples at this mill.

2-Nitrophenol. The compound 2-nitrophenol belongs to the chemical class known as nitrophenols. The nitrophenols represent a generic class of organic compounds that may contain from one to four nitro groups substituted on the phenol ring. They include the mono-, di-, tri-, and tetra-nitrophenols in various isomeric forms. Isomers of the dinitrocresols are sometimes included within this class of compounds.

Nitrophenols and nitrocresols are widely used in the U.S. as intermediates for the production of dyes, pigments, pharmaceuticals, rubber chemicals, lumber preservatives, photographic chemicals, and pesticidal and fungicidal agents. Although some nitrophenols are not produced commercially in substantial quantities, various nitrophenolic compounds are inadvertantly produced via microbial degradation of the pesticides parathion and 4,6-dinitro-o-cresol.

No sources of 2-nitrophenol in textile mill wastewaters were cited or suggested by anyone in the industry contacted in this study. Out of 418 questionnaire returns, 2 indicated "suspected presence" in the mill waste, but no sources were suggested. In the field sampling program, this toxic pollutant was detected in one secondary treated effluent at 4.1 ug/l. It was not detected in the raw wastewater sample at this mill.

4-Nitrophenol. The compound 4-nitrophenol belongs to the chemical class known as nitrophenols. The nitrophenols represent a generic class of organic compounds that may contain from one to four nitro groups substituted on the phenol ring. They include the mono-, di-, tri-, and tetra-nitrophenols in various isomeric forms. Isomers of the dinitrocresols are sometimes included within this class of compounds.

Nitrophenols and nitrocresols are widely used in the U.S. as intermediates for the production of dyes, pigments, pharmaceuticals, rubber chemicals, lumber preservatives, photographic chemicals, and pesticidal and fungicidal agents. Although some nitrophenols are not produced commercially in substantial quantities, various nitrophenolic compounds are inadvertantly produced via microbial degradation of the pesticides parathion and 4,6-dinitro-o-cresol.

The DETO survey results indicated that 4-nitrophenol may be present in some commercial dyes at less than 0.1 percent levels. Out of 418 questionnaire surveys, 2 indicated "suspected presence" in the mill waste, but no possible sources were suggested. In the field sampling program, this pollutant was detected at "less than 10 ug/l" in one of two secondary effluent samples at one mill. It was not detected in the raw wastewater samples at this mill.

2,4-Dinitrophenol. The compound 2,4-dinitrophenol belongs to the chemical class known as nitrophenols. The nitrophenols represent a generic class of organic compounds which may contain from one to four nitro groups substituted on the phenol ring. They include the mono-, di-, tri-, and tetra-nitrophenols in various isomeric forms. Isomers of the dinitrocresols are sometimes included within this class of compounds.

Nitrophenols and nitrocresols are widely used in the U.S. as intermediates for the production of dyes, pigments, pharmaceuticals, rubber chemicals, lumber preservatives, photographic chemicals, and pesticidal and fungicidal agents. Although some nitrophenols are not produced commercially in substantial quantities, various nitrophenolic compounds are inadvertantly produced via microbial degradation of the pesticides parathion and 4,6-dinitro-o-cresol.

The DETO survey results indicated that 2,4-dinitrophenol may be present in some commercial dyes at concentrations less than 0.1 percent. Out of 418 questionnaire returns, 4 indicated "suspected presence" in the mill waste. No possible sources were suggested. This toxic pollutant was not detected in any sample in the field sampling program.

<u>N-Nitrosodimethylamine</u>. The compound N-nitrosodiphenylamine belongs to the chemical class known as nitrosamines. The organic nitroso-compounds are a large group of chemicals characterized by a nitroso group (N=O) that is attached to the nitrogen of a secondary amine.

Patent applications show potential uses of nitrosamines in the manufacture of rubber, dyestuffs, gasoline additives, lubricating oils, explosives, insecticides, fungicides, dielectric fluids, acrylonitrile, plasticizers, industrial solvents, and hydrazine. At present, two major industries are involved in handling nitrosamines: organic chemicals manufacturing and rubber processing. Diphenylnitrosamine is the only nitrosamine which is produced in quantities greater than 450 kg. It is used as a vulcanizing retarder in rubber processing and in pesticides. Other nitrosamines are not produced commercially except as research chemicals.

N-nitrosodimethylamine is a possible trace constituent of some commercial dyes. The DETO survey results indicate that concentrations should be less than 0.1 percent. Out of 418 questionnaire returns, 5 indicated "suspected presence" in the mill waste. This pollutant was not detected in any sample collected in the field sampling program.

<u>Benzofluoranthene (3,4 and 11,12)</u>. The compounds 3,4- and 11,12-benzofluoranthene belongs to the chemical class known as polynuclear aromatic hydrocarbons (PAH's). PAH's are formed as a result of combustion of organic compounds without sufficient oxygen. This leads to the formation of C-H free radicals that can polymerize to form various PAH's. Domestic and industrial soots, coal tar, and pitch are the products of incomplete combustion of carbonaceous materials such as wood, coal, and oil. Naturally formed shale oil and petroleum contain PAH.

Using the EPA analytical protocol, the 3,4- and 11,12- isomers of benzofluoranthene are not distinguishable. No possible sources of this compound in textile mill wastewaters were found in this study. Out of 418 questionnaire returns, 1 indicated "suspected presence" in the mill waste, without suggesting any possible source. This pollutant was detected at "less than 10 ug/l" in one of two raw wastewater samples at one mill. It was not detected in the two secondary effluent samples.

Fluorene. Fluorene belongs to the chemical class of compounds known as polynuclear aromatic hydrocarbons (PAH's). PAH's are formed as a result of combustion of organic compounds without sufficient oxygen. This leads to the formation of C-H free radicals that can polymerize to form various PAH's. Domestic and industrial soots, coal tar, and pitch are the products of incomplete combustion of carbonaceous materials such as wood, coal, and oil. Naturally formed shale oil and petroleum contain PAH.

A possible source of fluorene in textile mill wastewaters suggested by the ATMI Task Force was some sanitary cleaning agents. Chemical references cite its use in dyestuffs, but this was not indicated by the DETO survey results. Out of 418 questionnaire returns, 1 indicated "known presence" and 4 indicated "suspected presence" in the mill wastes. No sources were suggested. This pollutant was detected in one raw wastewater sample at 15 ug/l. It was not found in any treated effluent samples.

Phenanthrene. Phenanthrene belongs to the chemical class of compounds known as polynuclear aromatic hydrocarbons (PAH's). PAH's are formed as a result of combustion of organic compounds without sufficient oxygen. This leads to the formation of C-H free radicals that can polymerize to form various PAH's. Domestic and industrial soots, coal tar, and pitch are the products of incomplete combustion of carbonaceous materials such as wood, coal, and oil. Naturally formed shale oil and petroleum contain PAH.

The only cited source of phenanthrene in textile mill wastewaters was dyes. The DETO survey results indicated that levels in some commercial dyes should be less than 0.1 percent. Out of 418 questionnaire returns, 3 indicated "suspected presence" in the mill wastes. This pollutant was not detected in the field sampling program.

Vinyl Chloride. Vinyl chloride is used in the manufacture of polyvinyl chloride, which is the most widely used synthetic plastic material throughout the world. Of the estimated million metric tons of vinyl chloride produced each year, 25 percent is manufactured in the U.S. Polyvinyl chloride is used for numerous products in the building and automobile industries, for electrical wire insulation, cables, piping, household equipment, clothing, toys, packaging for food products and medical supplies. The rubber, paper, and glass industries also depend heavily on the production of vinyl chloride. Polyvinyl chloride and vinyl chloride copolymers are distributed and processed in a variety of forms including dry resins, plastisol (dispersions in plasticizers), organosol (dispersion in plasticizers plus volatile solvent), and latex (colloidal dispersion in water). Latexes are used to coat or impregnate paper, fabrics, or leather.

No likely sources of vinyl chloride in textile mill wastewaters were suggested by any industry representatives. Out of 418 questionnaire returns, 5 indicated "suspected presence" in the mill waste, but no sources were suggested. In the field sampling program, it was detected in one raw wastewater sample at 11 ug/l. It was not detected in the treated waste effluent sample at this mill. There remains some question as to the validity of this analytical result because of the nature of this compound.

Dieldrin. Dieldrin has been one of the most widely used domestic pesticides. It is a chlorinated hydrocarbon compound. Although aldrin (see Group 2C) is used in greater quantity than dieldrin, aldrin quickly transforms into dieldrin in the environment. Hence, there is concern with both compounds. The primary use of the chemicals in the past was for control of corn pests, although they were also used by the citrus industry. Uses are restricted to those where there is no effluent discharge.

Aldrin use in the U.S. peaked at 8.6 million kilograms (19 million pounds) in 1966 but dropped to about 4.8 million kilograms (10.5 million pounds) in 1970. During that same period dieldrin use decreased from 0.45 million kilograms (1 million pounds) to 304,000 kilograms about (670,000 pounds). The decreased use has been attributed primarily to increased insect resistance to the two chemicals and to development and availability of substitute materials.

No general sources of dieldrin in textile mill wastewaters were suggested by any of the industry representatives. Out of 418 questionnaire responses, 1 indicated "known presence" in the mill wastes and cited moth proofing as the source. Dieldrin was detected in one wastewater sample at 0.2 ug/l. This analysis was carried out on 10 selected textile mill wastewater samples by EPA's Pesticide Monitoring Laboratory, and the finding of this toxic pollutant was confirmed by both GC/MS and FID-GC.

4,4'-DDT. Dichlorodiphenyl trichloroethane (DDT) and its metabolites are among the most widely distributed synthetic chemicals on earth. These pesticides are found in soils, runoff water, air, rainwater, and in the tissues of animals. Basic characteristics of DDT include persistence, mobility, and a broad range of toxicological effects.

No known sources of 4,4-DDT were suggested by the textile industry representatives other than the water supply and agricultural activities in the vicinity of the mill. Out of 418 questionnaire returns, 1 indicated "suspected presence" in the mill waste, but suggested no potential source. This toxic pollutant was detected in 1 of 10 selected textile mill wastewater samples by EPA's Pesticide Monitoring Laboratory. The concentration was 0.5 ug/l by GC analysis. This was confirmed by FID-GC, but could not be confirmed by GC/MS because of an interference. Florisil cleanup of the sample did not remove the interference.

Beryllium. Beryllium is a naturally occurring element that constitutes about 0.001 percent of the earth's crust. Environmental concentrations of beryllium are reported at 0.6 ng/l in seawater, while beryllium concentrations in U.S. surface water samples ranged from 10 to 1,220 ng/l, with a mean of 190 ng/l (20). Major uses of beryllium are in the manufacture of X-ray diffraction tubes and electrodes, in nuclear reactors, in the optical industry, and in the production of alloys.

No likely manufacturing-related sources of beryllium in textile mill wastewaters were suggested by any of the industry representatives. Out of 418 questionnaire returns, 2 indicated "known presence" and 5 indicated "suspected presence" in the mill waste, but only one respondent cited the potential source; "raw materials." In the field sampling program, beryllium was detected in one raw wastewater sample at "less than 40 ug/l." Other samples analyzed by the same laboratory were reported as "less than 5 ug/l." This was the lowest level reported by this laboratory, and is here regarded as being equivalent to "not detected." Beryllium was not detected in any of the samples (approximately 40 mills) analyzed by another laboratory. The latter laboratory worked to a minimum detection limit of 0.1 ug/l.

Group 2C - Potentially Significant in Textile Wastewaters: Not Detected

The toxic pollutants not detected in the field sampling program, but suggested as possibly present as an intermediate or contaminant in some textile chemicals are the following:

6. carbon tetrachloride
14. 1,1,2-trichloroethane
16. chloroethane
40. 4-chlorophenyl phenyl ether
50. dichlorodifluoromethane
54. isophorone
56. nitrobenzene
60. 4,6-dinitro-o-cresol
77. acenaphthylene

Also included in Group 2C are the remaining pesticides that could be present because of contamination of raw materials or agricultural activities that impact the mill:

89. aldrin
91. chlordane
93. 4,4'-DDE
94. 4,4'-DDD
95. alpha-endosulfan
96. beta-endosulfan
97. endosulfan sulfate
98. endrin
99. endrin aldehyde
100. heptachlor
101. heptachlor epoxide
102. alpha-BHC
103. beta-BHC
104. gamma-BHC (1i105. delta-BHC
113. toxaphene

<u>Carbon Tetrachloride</u>. Carbon tetrachloride is a haloalkane and is a dense, colorless liquid at room temperature. Approximately 450 million kilograms (one billion pounds) are produced annually in the U.S. The bulk of this production is used in the manufacture of fluorocarbons (95 percent in 1973), which are used primarily as aerosol propellants. However, the demand for carbon tetrachloride is expected to decrease as the use of aerosol products decreases. Other uses of carbon tetrachloride include: grain fumigation, where it is being largely replaced by other registered pesticide products; fire extinguishers; and in the dry cleaning industry as a degreaser, where it has been largely replaced by perchloroethylene. Carbon tetrachloride has been used as a deworming agent and anesthetic, but, because of adverse toxicity, these uses have been discontinued. Carbon tetrachloride has been found at low levels in plant and animal tissues, but does not appear to bioconcentrate to any appreciable extent.

Out of 418 questionnaire returns, 1 indicated "known presence" and 9 indicated "suspected presence" of carbon tetrachloride in the mill waste. One respondent cited dyes and another "raw material" as possible sources. This pollutant was not among those listed in the DETO survey results as believed present in commercial dyes, although that survey did not include dyes produced in smaller quantities.

<u>1,1,2-Trichloroethane</u>. The compound 1,1,2-trichloroethane belongs to the chemical class known as chlorinated ethanes. The chlorinated ethanes, which are produced in relatively large quantities, are used for the production of tetraethyl lead and vinyl chloride, as industrial solvents, and as intermediates in the production of other

organochlorine compounds. Some have been found in drinking waters, in natural waters, and in aquatic organisms and foodstuffs.

This toxic pollutant may find application in some textile mills in scouring or as a spot remover. Out of 418 questionnaire returns, 9 indicated "suspected presence" in mill waste, with one respondent citing dyes as the potential source. This was not confirmed by the DETO survey results.

Chloroethane. Chloroethane belongs to the chemical class known as chlorinated ethanes. The chlorinated ethanes, which are produced in relatively large quantities, are used for the production of tetraethyl lead and vinyl chlorides, as industrial solvents, and as intermediates in the production of other organochlorine compounds. Some have been found in drinking waters, in natural waters, and in aquatic organisms and foodstuffs.

Out of 418 questionnaire returns, 1 indicated "known presence" and 8 indicated "suspected presence" of chloroethane in the mill waste. Potential sources cited by two respondents were "raw materials." No other information about sources of this compound in textile mill wastewaters was suggested by the industry.

4-Chlorophenyl Phenyl Ether. The compound 4-chlorophenyl phenyl ether belongs to the class of compounds known as haloethers. These are compounds that contain an ether moiety (R-O-R) and halogen atoms attached to the aryl or alkyl groups. Chloroethers appear to be the most important haloethers used commercially and can be divided into two categories, alpha- and non-alpha- chloroethers. Chloromethyl methyl ether (CMME) is the only alpha haloether of commercial significance and is used primarily in the synthesis of strong base ion exchange resins used in water conditioning and for chemical separation processes. However, CMME preparations are usually contaminated with 1 to 8 percent bis(chloromethyl)ether (BCME) which has been demonstrated to be a potent carcinogen.

The beta-chloroethers are widespread environmental contaminants. It has been suggested that they are produced or may be formed as by-products in sizable quantities, are released to and appear to persist in the environment, can pass through drinking water treatment plants, and may be carcinogenic. Bis (2-chloroethyl) ether (BCE) is used as a dewaxing agent for lubricating oils and is a useful solvent for naphthenic components. BCE has also been used to separate butadiene from butylene. The second major use of bis (2-chloroethyl) ether is in the textile industry as a cleaning agent, a wetting agent and penetrant in combination with diethylene glycol, sulphonated oils, etc. The compound generally is a good solvent for tars, fats, waxes, oils, resins and pectins, and will dissolve cellulose esters when used with 10-30 percent ethanol.

The ATMI Task Force suggested that this compound might find general applications as a fungicide or bactericide, although not necessarily in textile manufacturing operations. Out of 418 questionnaire returns, 4 indicated "suspected presence" in the mill waste. No potential sources were cited. This compound is reportedly used in some proprietary sanitary cleaning compounds.

Dichlorodifluoromethane. Dichlorodifluoramethane belongs to the class of compounds known as halomethanes. These compounds are a subcategory of halogenated hydrocarbons. Dichlorodifluoromethane has been referred to as difluorodichloromethane, Freon 12, Acton 6, Genetron 12, Halon, and Isotron 2. Freon compounds are organic compounds that contain fluorine. They have a high degree of chemical stability, relatively low toxicity, and are nonflammable. Freon compounds have found many applications ranging from use as propellants to refrigerants and solvents.

No specific uses of dichlorodifluoromethane were reported by any textile industry representative, although it might have applications in textile mills and their laboratories. It has no particular process-related applications, however. None of the questionnaire returns listed it as "known" or "suspected presence" in the mill waste.

Isophorone. Isophorone is an industrial chemical synthesized from acetone and is used commercially as a solvent or cosolvent for finishes, lacquers, polyvinyl and nitrocellulose resins, pesticides, herbicides, fats, oils, and gums. It is also used as a chemical feedstock for the synthesis of 3,5 xylenol, 2,3,5-trimethyl cyclobexanol, and 3, 5-dimethylaniline.

Out of 418 questionnaire returns, 1 indicated "suspected presence" in the mill waste, citing dyes as the potential source. This was not indicated as a common source by the results of the DETO survey.

Nitrobenzene. Nitrobenzene is a pale yellow liquid with a sweet but sickening odor. It is produced by the reaction of nitrous and sulfuric acid and benzene. Most of the nitrobenzene produced is reduced to analine and other dye intermediates for use in soaps and shoe polishes. On a small scale, it is used as a mild oxidizing agent.

Out of 418 questionnaire returns, 7 indicated "suspected presence" of nitrobenzene in the mill waste, with 1 respondent citing defoamer as the potential source, and another citing naphthol dyes. This latter source was not indicated as common by the results of the DETO survey.

4,6-Dinitro-o-Cresol. The compound 4,6-dinitro-o-cresol belongs to the chemical class known as nitrophenols. The nitrophenols represent a generic class of organic compounds that may contain from one to four nitro groups substituted on the phenol ring. They include the mono-, di-, tri-, and tetra-nitrophenols in various isomeric forms. Isomers of the dinitrocresols are sometimes included within this class of compounds.

Nitrophenols and nitrocresols are widely used in the U.S. as intermediates for the production of dyes, pigments, pharmaceuticals, rubber chemicals, lumber preservatives, photographic chemicals, and pesticidal and fungicidal agents. Although some nitrophenols are not produced commercially in substantial quantities, various nitrophenolic compounds are inadvertantly produced via microbial degradation of the pesticides parathion and 4,6-dinitro-o-cresol.

The use of 4,6-dinitro-o-cresol as a constituent of dyestuff was not indicated as a common source by the results of the DETO survey. Out of 418 questionnaire returns, 2 indicated "suspected presence" in the mill waste. No potential sources were suggested.

Acenaphthylene. Acenaphthylene belongs to the chemical class of compounds known as polynuclear aromatic hydrocarbons (PAH's). PAH's are formed as a result of combustion of organic compounds without sufficient oxygen. This leads to the formation of C-H free radicals that can polymerize to form various PAH's. Domestic and industrial soots, coal tar, and pitch are the products of incomplete combustion of carbonaceous materials such as wood, coal, and oil. Naturally formed shale oil and petroleum contain PAH.

Out of 418 questionnaire returns, 3 indicated "known presence" and 2 indicated "suspected presence" of acenaphthylene in the mill waste. Two respondents cited direct dyes as the potential sources. This was not indicated as a common source by the results of the DETO survey.

Group 3 - Not Considered Significant in Textile Wastewaters

Based on the findings of this study, the following toxic pollutants are not considered significant in textile mill wastewater. They were not detected in the field sampling program and were not suggested as possibly present in mill wastes due to manufacturing operations or from other sources. It should be noted that two of the Group 3 pollutants, asbestos and dioxin, were not analyzed for in the field sampling program because of analytical constraints. Asbestos fibers have been detected in some municipal water supplies, but at this time there are no data to suggest that asbestos is a significant pollutant in textile mill wastewaters. It should be noted that asbestos textile products are covered by another EPA point source category. Dioxin is extremely toxic, and there is no evidence that it is commonly present in textile mill wastewaters.

Group 3 comprises the following toxic pollutants:

2. acrolein
12. hexachloroethane
15. 1,1,2,2-tetrachloroethane
17. bis (chloromethyl) ether
18. bis(2-chloroethyl) ether
19. 2-chloroethyl vinyl ether
26. 1,3-dichlorobenzene
30. 1,2-trans-dichloroethylene
33. 1,3-dichloropropylene
35. 2,4-dinitrotoluene
39. fluoranthene
41. 4-bromophenyl phenyl ether
42. bis(2-chloroisopropyl) ether
43. bis(2-chloroethoxy) methane
47. bromoform
51. chlorodibromomethane
52. hexachlorobutadiene
53. hexachlorocyclopentadiene
69. di-n-octyl phthalate
72. 1,2-benzanthracene
73. benzo(a)pyrene
76. chrysene
79. 1,12-benzoperylene
82. 1,2,5,6-dibenzanthracene
83. indeno (1,2,3-cd)pyrene
106. PCB-1242
107. PCB-1254
108. PCB-1221
109. PCB-1232
110. PCB-1248
111. PCB-1260
112. PCB-1016
116. asbestos
129. dioxin

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

This section describes the technologies that are available to conserve water and reduce the constituents in textile wastewater discharges. There are two major approaches available: 1) in-plant controls and process changes and 2) end-of-pipe treatment. Programs combining elements of both approaches are required for many mills in the industry. Individual mills should consider both approaches and determine which specific combination is best suited to their particular situation.

In-plant controls and process changes, which are described below, are measures taken to reduce hydraulic and pollutant loadings originating from mill operations. At the present time, the use of such measures is limited. In general, most textile mills use water once and discharge it. There may exist a lack of communication and coordination between individuals and activities inside textile mills and personnel responsible for end-of-pipe water pollution control. The lack of attention in such mundane areas as housekeeping and leak control is an indication that more sophisticated measures are also lacking. These situations can be attributed to several factors, including low costs for water and lack of recognizable incentives to practice conservation. These aspects are changing today and much greater attention is being focused on in-plant control measures because of economic, environmental, and energy considerations.

End-of-pipe treatment technologies for textile mill wastewaters have been researched and developed for decades. As described subsequently in this section, most of the direct-discharge mills in the industry provide end-of-pipe treatment and many indirect dischargers also provide treatment. Preliminary treatment, biological treatment, chemical processes, physical separation methods, and sorption systems are described after the discussion of in-plant controls. Each system is described along with specific case studies.

IN-PLANT CONTROLS AND PROCESS CHANGES

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

It is convenient to divide in-plant measures into five types as follows: 1) water reuse, 2) water reduction, 3) chemical substitution, 4) material reclamation, and 5) process changes and new process technology. Water reuse and water reduction measures simply lower water usage rates. This results in a lower hydraulic loading on treatment facilities that in turn may yield an improved effluent quality. In other situations, smaller treatment units may be used, involving less capital and lower operating costs. Chemical substitution or material reclamation may reduce conventional pollutant loadings on treatment facilities or eliminate or reduce the levels of toxic pollutants or other undesirable constituents in the wastewater. Process changes can result in water and pollutant reductions through improved efficiency and process control.

Summary of In-Plant Controls Data

Surveys from 541 textile mills were received during the initial phase of the study. Of these, 152 provided relevant information about in-plant production process control. In some instances, this information was supplemented by telephone calls to knowledgeable mill personnel. A summary of the responses, listed by subcategory, is provided in Table VII-1. The number of controls cited totaled 195, with many facilities identifying more than one control measure. However, the quantitative accuracy of the in-plant control information developed from the survey is somewhat questionable due to confusion as to what qualifies as an in-plant control measure. The following is an example of the kinds of problems encountered.

Forty-seven mills mercerize cotton to some extent. Twenty-six of these practice caustic recovery while 18 do not. The practices at the other 3 mills are unknown. Eleven of the mills practicing caustic recovery considered it to be an in-plant control measure. Evidently, the others considered it to be a common and expected aspect of the mercerizing process, since they did not list it as an in-plant control. This type of inconsistency may exist elsewhere in the survey data. To date, most in-plant control measures have been implemented for reasons other than, or in addition to, water pollution control.

Water Reuse

Water reuse, as considered here, includes those situations that 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 here, since it does not accomplish such reductions. The two major water reuse measures available to textile mills are: 1) reuse of relatively clean cooling water in operations requiring hot water, and 2) reuse of process water from one operation in a second, unrelated operation.

TABLE VII-1
REPORTED IN-PLANT CONTROL MEASURES - RESULTS OF INDUSTRY SURVEY

	Subcategory	Water Reuse	Water Reduction	Chemical Substitution	Material Reclamation	Total
1.	Wool Scouring	2	1	0	1	4
2.	Wool Finishing	2	4	1	0	7
4.	Woven Fabric Finishing	28	20	17	16	81
5.	Knit Fabric Finishing					
	Fabric Processing	24	8	9	1	42
	Hosiery Processing	1	0	1	0	2
6.	Carpet Finishing	10	2	3	3	18
7.	Stock & Yarn Finishing	21	9	3	1	34
8.	Nonwoven Manufacturing	2	1	1	0	4
9.	Felted Fabric Processing	2	0	1	0	3
	All Subcategories	92	45	36	22	195

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

Reuse of certain process water elsewhere in mill operations can also result in significant wastewater reductions. Many examples have been cited in the literature regarding potential reuse possibilities. These include reuse of wash water from bleaching in caustic washing and scour make-up and rinse water, reuse of scouring rinses for desizing or washing printing equipment, reuse of mercerizing wash water to prepare scour, chlorine bleach, and wetting out baths, and similar activities. Careful analysis will be required prior to implementation of these and similar measures to determine the feasibility for each situation.

Ninety-two mills in the survey appear to have instituted some form of water reuse. To be considered here, the water had to have been discharged previously without reuse. By far the most common situation is the use of cooling water a second time to utilize its energy value. The water is often passed through a heat exchanger and temperature increases as great as 33°C (91°F) have been reported. Although most mills identifying this type of water reuse began the practice in the mid-seventies to conserve energy, it is possible that similar systems were instituted elsewhere earlier, and are no longer considered to be in-plant control measures by mill personnel. At some mills, both energy and water savings were major considerations in instituting reuse, while at other mills one or the other predominated. Energy savings commonly varied from 1 billion to 100 billion Btu/yr, while water savings varied from a few thousand gpd to 100,000 gpd or more. Costs to institute these controls were often less than $5,000, although some facilities reported costs of more than $50,000. The principal cost items were pumps, piping modifications, and hot water storage tanks.

As energy costs rise and wastewater treatment requirements become more stringent, 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 is also 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 so it is expected that more reuse of this nature will also be forthcoming.

Water Reduction

Three in-plant control measures that are considered forms of water reduction are: 1) countercurrent flow washing, 2) conservation, and 3) process modifications. Just as water reuse results in water reduction, certain water reduction measures (e.g., countercurrent flow washing) can be considered water reuse techniques; the distinction between these two areas is not sharply defined. However, in general, water reuse is the use of the same water more than once while water reduction is the use of less water.

The countercurrent-flow system is based on the principle that wash water is not used effectively if it is cleaner than the fabric upon leaving the washbox. In counter-flow processing, the water flows through the process in the direction opposite to that of the material. For example, in counter-flowing wash boxes on a continuous range, the water is reused in each of the boxes counter-flowed. In this way, the water is discharged after contacting the material when it contains the greatest 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. In some of these mills, counter-flowing wash boxes have been in use for a long time. However, many mills still do not counterflow wash waters, especially where water is inexpensive; this can be expected to change as water and waste treatment become more costly (60). In some instances, wash and rinse waters may be used as make-up water for certain processes, resulting in possible chemical savings as well.

Conservation measures include a variety of steps that can be taken to reduce water use in textile mills. "Good housekeeping" has frequently been cited as a valuable in-plant control. This consists of maintaining close control over mill operations to avoid accidental loss of process chemical baths and avoiding the preparation of larger batches than required, with resultant wastage of the excess. Supervision for insuring efficient operation of in-plant controls such as countercurrent flow systems is included. It also includes reduction of such things as dirt, grease, and rust in production areas to avoid unnecessary washing and processing of soiled material. Other measures that have been advised are the construction of retaining walls, splashboards, and sills, plus proper maintenance of machinery and plumbing to minimize process fluid losses through spillage and leaks. Greater use of liquid level controls, flow indicators and meters, and automatic shut-off devices also reduce water requirements at textile mills.

Process modifications (as opposed to changes) to reduce water use that can be simply implemented 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 that can be incorporated into processes to assist in uniformity of application, reduction of rework, control of pH and temperature, or performance of similar functions may be employed to achieve reductions in water and chemical usage. Another process modification is to pump process liquor to a storage tank where it is saved for reuse in the makeup of the next similar bath. This and similar material recovery techniques are more appropriately considered as material reclamation activities.

Based on questionnaire and telephone surveys, 45 mills have instituted water reduction control measures. The most common water reduction measure identified was countercurrent flow of water during wet processing operations. Countercurrent flow in scouring and desizing, and rinse water use in bleaching, dyeing, and mercerizing have been instituted at various mills. As discussed in the section on water reuse, energy and/or water savings can be substantial and costs for implementation can vary considerably. Conservation measures include a variety of steps taken to reduce water use. Use of automatic shut-offs, level and flow control valves and meters, and similar modifications to existing equipment and plumbing have been installed economically in terms of water and energy savings at some mills.

Some process modifications have been implemented quite simply. A few mills have found that they can utilize 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 usage generally require capital investments. Such modifications are considered to be 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 are less polluting or more amenable to wastewater treatment. A number of process chemical substitutions have been suggested or developed for the textile industry, and it appears from the levels and numbers of toxic pollutants found in secondary effluents that this area of control may play an important role in the future. For any substitution, however, a careful evaluation should be made to ascertain that one pollution problem is not being substituted for another. Some examples of process chemical substitution are discussed below.

Foaming problems in treatment facilities and receiving streams have been solved by substituting biodegradable, low-foaming detergents for the so-called "hard" detergents. In another area, potentially toxic pollutants, especially certain organics and heavy metals, have been reduced or eliminated by substitution. One example is switching from chromate oxidizers to hydrogen peroxide or iodates in certain dyeing processes to eliminate chromium. The replacement of soap with sulfuric acid in wool fulling operations is a substitution measure that has resulted in lower BOD loadings. Mineral acids have been substituted for high BOD acetic acid in various dyeing processes, offering an advantage in terms of wastewater treatability. And, the substitution of mineral oils with nonionic emulsifiers for the more traditional olive oil for carding wool has also resulted in lower pollutant levels.

Starch wastes from desizing have been the single greatest source of BOD at many mills. Consequently, low BOD substitutes, such as CMC, PVA, and PAA, have become useful to reduce BOD loadings on treatment plants. However, a secondary consideration should be the net effect on the environment. These low-BOD, high-COD sizes contribute substantially to the ultimate oxygen demand of the receiving stream. In view of this, the following from a report prepared for the American Textile Manufacturers Institute (61) 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 on removal. Certainly, in terms of conventional biological systems, low-BOD chemicals will not lose their significance. However, as physical-chemical 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 noted 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 such control. One Wool Finishing mill reported that savings in labor and other processing costs more than offset the higher cost of dyes substituted for the traditional chrome dyes. BOD reductions were achieved at some mills by the following substitutions: synthetic warp sizes for starch, low BOD detergents for those with high BOD, and other pH adjusters for acetic acid. In addition, nonbiodegradable chemicals were replaced with substances that are biodegradable, and certain undesirable compounds and metals eliminated from process operations at some mills.

A more general chemical substitution known as solvent processing is more accurately classified as a process change and was not identified as an in-plant control by mill respondents.

Material Reclamation

Material reclamation measures are often implemented to reduce processing costs, reduction of pollutant loadings being a secondary benefit. As has been 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 reclaim PVA and one reclaims 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 some 22 mills. It is anticipated that chemical and wastewater treatment costs will make material conservation and recovery more important in the future.

Process Changes and New Process Technology

Process changes comprise a group of related measures that may be used to achieve benefits in the four areas noted. They result in reductions of hydraulic and/or pollutant loadings to treatment systems, and, in some cases, do so quite significantly.

Employment of process changes and new process technology holds great promise for reducing hydraulic and pollutant loads from textile mills. Technological advances in fibers, process chemicals and other raw materials, and fibers process equipment are constantly being made, and in general these changes have resulted in lower hydraulic and conventional pollutant loadings (2). It is expected that this trend will continue, but the nature of future textile processing is difficult to predict with certainty. Some of the current process changes and trends available to the textile industry are discussed below.

Solvent processing has been the most discussed of all the new process technologies. In general it has not yet lived up to its early promise, except for certain 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 convincing has been the inability to achieve the required levels of solvent recovery necessary to make the processes 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 has been the emission of unrecovered solvent to the work place or the atmosphere. In spite of these problem areas, some textile equipment manufacturers believe that research and development will overcome the problems and result in processes and equipment for large, nonaqueous systems that can be substituted for the various processes presently being used (62). Thus, the potential of solvent processing for reducing wastewater problems in the textile industry cannot be estimated at the present.

A more feasible method of reducing hydraulic and pollutant loadings in the industry at the present time is to change processes and material flow procedures. It has been noted (63) that continuous operations generally require less space, water, and process chemicals than do batch operations. A second process change that may be employed to reduce water use is to substitute standing baths and rinses for running ones. Rope washers are reportedly more effective than open-width washers in reducing water use. Significant water use reductions can also be achieved by combining separate operations, such as scouring and dyeing in the finishing of synthetic fibers and the desizing and scouring of cotton fibers, whenever possible.

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 perhaps most importantly reduce the level of toxic dye carriers, as compared to atmospheric dyeing. Nevertheless, technological advancements in textile machinery should be continually sought. Chemical manufacturers must be urged to provide chemical modifications that assist in recovery or removal of chemicals by unit treatment methods, and equipment manufacturers must be urged to cooperate in design of equipment with an eye toward pollution abatement. It is with the textile producer, however, that the responsibility lies for defining the problem areas and offering the specific direction for equipment manufacturers to follow.

END-OF-PIPE TREATMENT TECHNOLOGIES

End-of-pipe treatment of combined waste streams is currently the principal approach being taken by the textile industry to remove or reduce the pollutant present in the waste from the various wet-processing operations. This has been, and seems to remain, the approach because of the difficulty of segregating waste streams at existing facilities. However, new facilities will no doubt be designed so that the more concentrated and more troublesome wastes can be segregated and treated independently. This will certainly be the case if toxic pollutants are to be controlled and chemical substitutions are not available.

It is convenient to discuss the applicable end-of-pipe treatment technologies as: 1) preliminary measures (screening, neutralization, and equalization), 2) biological processes (aerated lagoons, activated sludge, biological beds, stabilization lagoons), 3) chemical processes (coagulation, precipitation, and oxidation), 4) physical separation methods (filtration, hyperfiltration, ultrafiltration, dissolved air flotation, stripping, and electrodialysis), and 5) sorption systems (activated carbon, and powdered activated carbon). A summary of the current end-of-pipe treatment practices by the mills surveyed during this study, and discussions of the individual technologies noted above follow.

Summary of Current Practices

The information developed in this study on current end-of-pipe treatment practices by the wet-processing mills surveyed is summarized in Table VII-2. The table illustrates that for the direct dischargers, 20 percent provide no wastewater treatment, 7 percent provide only preliminary treatment (i.e., neutralization, screening, equalization, heat exchange, disinfection, primary sedimentation, and/or flotation), 65 percent provide biological or an equivalent level of treatment (i.e., aerated or unaerated lagoons, biological filtration, activated sludge, and chemical coagulation/flocculation without preceding biological treatment), and 8 percent provide an advanced level of treatment (i.e., activated carbon, chemical coagulation following biological treatment, ozonation, filtration, ion exchange, and membrane processes). For the indirect dischargers, 57 percent provide no treatment, 33 percent provide preliminary treatment, 9 percent provide biological or an equivalent level of treatment, and 0.1 percent (1 mill) provide an advanced level of treatment. Approximately 21 percent of the mills surveyed (72 percent of the direct dischargers and 9 percent of the indirect dischargers) provide biological or an equivalent level of treatment as a minimum.

Specific quantitative information about the treatment technologies employed by the mills surveyed is presented in Table VII-3 for mills that discharge directly to a receiving water and in Table VII-4 for mills that discharge indirectly through POTW.

For both direct- and indirect-discharge mills that have treatment facilities, well over half provide some form of screening, while less than half have equalization and only about 20 percent neutralize. Nearly 68 percent of the direct dischargers employ activated sludge in their treatment system. For estimating the costs of additional treatment technologies for the direct dischargers, the base for existing treatment comprised a sequence of screening, activated

TABLE VII-2
WASTEWATER TREATMENT STATUS - WET PROCESSING MILLS SURVEYED

Subcategory	No Treatment		Preliminary		Biological or Equivalent		Advanced		Treatment Unclassified			Totals		
	D	I	D	I	D	I	D	I	D	I	U	D	I	All Mills
1. Wool Scouring	1	5	2	3	4	2	0	0	0	0	0	7	10	17
2. Wool Finishing	2	9	0	11	8	4	0	0	0	0	3	10	24	37
4. Woven Fabric Finishing	9	128	8	65	60	23	5	0	0	8	30	82	224	336
5. Knit Fabric Finishing														
Fabric Processing	10	135	0	59	31	24	7	0	0	3	13	48	221	282
Hosiery Processing	4	101	0	43	4	5	0	1	0	2	0	8	152	160
6. Carpet Finishing	1	6	1	34	10	2	1	0	0	0	3	13	42	58
7. Stock & Yarn Finishing	3	108	3	51	26	14	4	0	0	2	6	36	175	217
8. Nonwoven Manufacturing	9	11	0	11	2	3	1	0	0	0	1	12	25	38
9. Felted Fabric Processing	1	1	1	12	3	0	0	0	0	1	1	5	14	20
All Subcategories	40	504	15	289	148	77	18	1	0	16	57	221	887	1,165

Note:
D refers to direct discharger, I to indirect dischargers, and U to unclassified mill

Preliminary - neutralization, screening, equalization, heat exchange, disinfection, primary sedimentation, and/or flotation

Biological or Equivalent - aerated and unaerated lagoons, biological filtration, activated sludge, chemical coagulation/flocculation without preceeding biological treatment

Advanced - activated carbon, chemical coagulation following biological treatment, ozonation, filtration, ion exchange, membrane processes, etc.

TABLE VII-3
EXISTING TREATMENT TECHNOLOGIES - DIRECT DISCHARGERS

		Treatment																
		Physical						Biological					Chemical			Tertiary		Other
Subcategory	No. of Mills	Sc	Eq	1°	2°	Sk	Fi	AS	A1	A2	An	TF	Ne	CC	Ox	AC	PC	
1. Wool Scouring	6	3	1	2	3			3		1					2			3
2. Wool Finishing	5	4	2		3			3	2	2			3	1				
4. Woven Fabric Finishing	56	39	21	4	41		2	40	13	16		2	13	8	19	1		9
5. Knit Fabric Finishing																		
Fabric	29	20	10		23	1	5	23	5	9			6	3	20			5
Hosiery Products	2	1			2			2										
6. Carpet Finishing	11	8	4	2	6		1	6	4	5			3		5		3	2
7. Stock & Yarn Finishing	29	17	13	4	18		3	18	8	9			7	2	12			4
8. Nonwoven Manufacturing	1			1					1					1				
9. Felted Fabric Processing	3	1	1		1			1		2					2			2
Total	142	93	52	13	97	1	11	96	33	44	0	2	32	15	60	1	3	25

Note:
Sc = Screening
Eq = Equalization
1° = Primary Sedimentation
2° = Secondary Sedimentation
Sk = Skimming
Fi = Filtration
AS = Activated Sludge
A1 = Aerated Lagoon
A2 = Facultative or Tertiary Lagoon
An = Anaerobic Lagoon
TF = Trickling Filter
Ne = Neutralization
CC = Chemical Coagulation
Ox = Oxidation, incl. Disinfection
AC = Activated Carbon
PC = Powdered Activated Carbon

TABLE VII-4
EXISTING PRETREATMENT TECHNOLOGIES - INDIRECT DISCHARGERS

		Treatment																
		Physical						Biological					Chemical			Tertiary		Other
Subcategory	No. of Mills	Sc	Eq	1°	2°	Sk	Fi	AS	A1	A2	An	TF	Ne	CC	Ox	AC	PC	
1. Wool Scouring	2	1		1						2								1
2. Wool Finishing	10	8	4		2			2	2				3	1	1			1
4. Woven Fabric Finishing	46	25	23	2	3		1	1	6	3			8	4	1			3
5. Knit Fabric Finishing																		
Fabric	42	17	18	1	2			2	11	5			3	1	3			4
Hosiery Products	20	12	7		1		1	1	2	2			2					1
6. Carpet Finishing	24	23	9	2	1	1		1			1		2	2	2			1
7. Stock & Yarn Finishing	43	21	26	7	4		1	4	2	3			13	2	4			4
8. Nonwoven Manufacturing	6	2	4							1			2					
9. Felted Fabric Processing	7	5	2	1									5					
Total	200	114	93	14	13	1	3	11	23	16	1	0	38	10	11	0	0	15

Note:
Sc = Screening
Eq = Equalization
1° = Primary Sedimentation
2° = Secondary Sedimentation
Sk = Skimming
Fi = Filtration
AS = Activated Sludge
A1 = Aerated Lagoon
A2 = Facultative or Tertiary Lagoon
An = Anaerobic Lagoon
TF = Trickling Filter
Ne = Neutralization
CC = Chemical Coagulation
Ox = Oxidation, incl. Disinfection
AC = Activated Carbon
PC = Powdered Activated Carbon

sludge, and secondary sedimentation as the major treatment units. Basically, this is the recommended BPT. For the indirect dischargers, the base for estimating costs assumed that no treatment was currently provided.

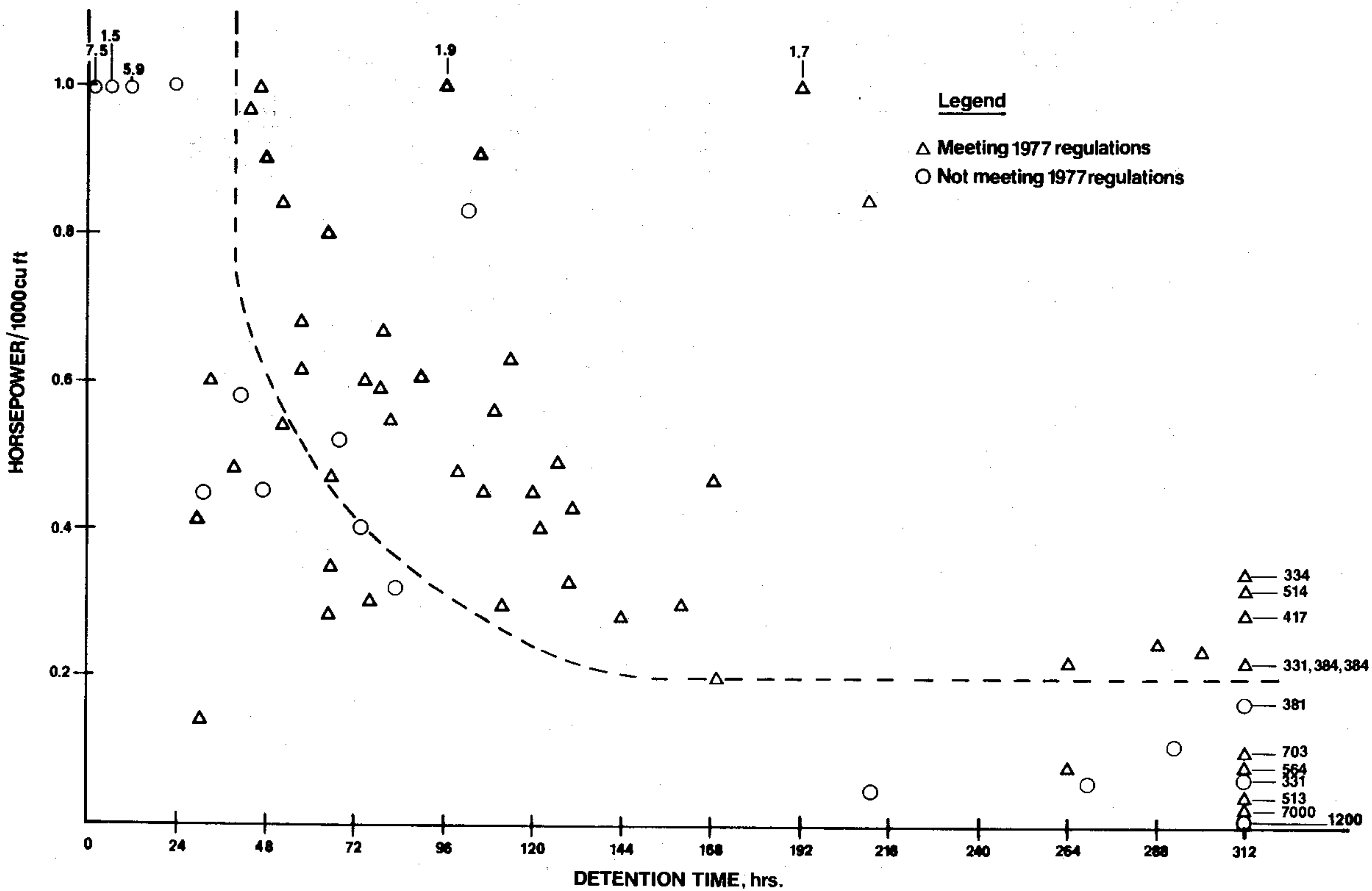
A detailed study of the effectiveness of the recommended BPT in the textile industry was carried out using the questionnaire results and supporting monitoring data reports. The extended-aeration mode of operating activated sludge systems is commonly used by direct-discharge mills. An analysis of the available data indicated that the two principal design variables affecting the quality of an aeration basin effluent are detention time (hours) and aeration horsepower per unit volume of the basin (hp/1000 cu ft). An analysis of treatment plants with the recommended BPT was carried out in order to determine a minimum horsepower:detention time value for biological treatment systems that, when used, would effect an effluent meeting the 1977 requirements. It was found that a total of 69 treatment plants in Subcategories 4, 5, 6, and 7 employed the recommended BPT. A graphical optimization procedure was applied to this list of 69 plants with the results shown in Figure VII-1. It was found that 40 of 42 (95 percent) of those plants maintaining a minimum detention time of 40 hours, a minimum of 0.2 horsepower per 1,000 cubic feet of basin volume, and a minimum of 30 horsepower-hours per 1,000 cubic feet met the 1977 effluent requirements.

It may be noted from Figure VII-1 that a very long detention time may compensate for inadequate aeration horsepower, but that the reverse is not true. This emphasizes the importance of designing aeration basins with sufficient detention time. Factors such as spacing and number of aerators (proper mixing) and adequate recycle of activated sludge are also important factors to achieve proper performance.

The relative merit of polishing ponds as an effective treatment technology was examined in conjunction with the above investigation. Of the 69 treatment plants examined, 23 utilized polishing ponds. Ten of these are among the 42 plants having at least the minimum recommended detention times and aeration values; only one failed to meet the 1977 effluent requirements. The remaining 13 plants with polishing ponds do not have the minimum recommended detention times and aeration values; 5 meet the 1977 effluent requirements, indicating a benefit due to the polishing ponds. Closer inspection, however, reveals that 2 of these 5 plants treat very weak influent waste, 1 of the other 3 plants almost meets the calculated minimum required detention time and aeration value, and the remaining 2 plants have aeration basin detention times in excess of 10 days. It seems possible that these 5 plants might meet the effluent requirements without the polishing ponds. The 8 plants not having the minimum detention time and aeration horsepower requirements were not benefited by their polishing ponds. In addition, as noted above, 1 plant having the minimum

FIGURE VII-1

DETENTION TIME VS AERATION HORSEPOWER PER UNIT VOLUME OF BASIN - PLANTS WITH BPT TECHNOLOGY



required detention time and aeration horsepower requirement failed to meet the effluent requirements, possibly due to the polishing pond. On the basis of these findings, the effectiveness of polishing ponds in upgrading textile mill treatment operations must be questioned.

1. Preliminary Measures

a. Screening

Screening is a physical unit operation and is usually the first operation employed in wastewater treatment. Based on size of openings (1/4 inch or greater or less than 1/4 inch), screens may be classified as coarse or fine. Coarse screens typically consist of parallel bars, rods or wires, grating, wire mesh or perforated plate. The opening may be of any shape, circular or rectangular slots being the most common. They may be "hand cleaned" or "mechanically cleaned" and have the primary function of removing rags, sticks, and similar coarse solids that may clog the pipes, pumps, valves, or other mechanical equipment of the treatment system. Fine screens serve a more definite role in the removal of pollutant solids and may include inclined disks or drums, static plates and mesh units, and vibratory mesh units. These may be cleaned by continuous water spray, by mechanically driven brushes, or, in the case of the vibratory type, automatically by nature of the design. They serve to remove floc, strings, short fibers, vegetable matter, or other small solids that may also clog or damage equipment or may form a mat or scum layer over aeration basins.

Industry Application. Both coarse and fine screening is practiced in the textile industry. A summary of the application by each subcategory for both direct and indirect dischargers is provided in Table VII-5. The table represents those mills that returned detailed questionnaires and involves the same data base noted previously in this section under "Summary of Current Practices." Only the highest level of screening at each plant is noted in the tabulation.

Coarse static screening predominates as the sole screening type for both the direct and indirect dischargers. Approximately 40 percent of the direct dischargers and nearly 25 percent of the indirect dischargers report static coarse screening as the only screening in their treatment systems. Fine screening (static, mechanical, hydrosieve, vibrating) is practiced by 34 percent of the direct dischargers and 31 percent of the indirect dischargers providing detailed survey information.

Nearly all of the mills in the Wool Finishing and Carpet Finishing subcategories provide some type of screening. This is believed to be because, in both subcategories, fibers are apt to be more plentiful in the wastewater. Another reason that may explain the high use of screens by carpet mills is that most of these mills are indirect

TABLE VII-5
WASTEWATER SCREENING BY TEXTILE INDUSTRY - RESULTS OF INDUSTRY SURVEY

	Mills Employing Screens														
	Coarse				Fine									
	Static		Mechanical		Static		Mechanical		Hydrosieve		Vibrating		Mills in Survey	
Subcategory	D	I	D	I	D	I	D	I	D	I	D	I	D	I
1. Wool Scouring	2	1	1	0	0	0	0	0	0	0	0	0	6	2
2. Wool Finishing	3	2	0	3	0	0	0	0	1	0	1	3	5	10
4. Woven Fabric Finishing	24	14	2	1	7	5	1	0	2	2	3	3	56	46
5. Knit Fabric Finishing Fabric Processing	13	9	0	0	4	5	2	1	0	0	0	2	29	42
Hosiery Processing	1	6	0	0	0	4	0	1	0	0	0	0	2	20
6. Carpet Finishing	2	3	0	1	3	12	2	5	1	2	0	0	11	24
7. Stock & Yarn Finishing	10	8	1	0	3	10	0	1	2	1	1	1	29	43
8. Nonwoven Manufacturing	0	1	0	0	0	0	0	1	0	0	0	0	1	6
9. Felted Fabric Processing	0	1	0	0	1	0	0	1	0	0	0	3	3	7
All Subcategories	55	45	4	5	18	36	5	10	6	5	5	12	142	200

Note: D refers to direct discharger and I refers to indirect discharger.

dischargers and are required by the municipalities treating their waste to practice screening.

b. Neutralization

Neutralization is the process of adjusting the pH so that the waste is within acceptable limits for discharge to a receiving body or subsequent treatment plant operations. Generally, a pH range of 6.0 to 9.0 is considered acceptable. Neutralization of acidic waste may be accomplished by: 1) mixing with an on-site alkaline waste stream; 2) passing through beds of limestone; 3) mixing with lime slurries or dolomite lime slurries; or 4) adding solution of caustic soda (NaOH) or soda ash (Na_2CO_3). Alkaline waste may be neutralized by: 1) mixing with an on-site acidic waste stream: 2) blowing waste boiler flue gas through the waste; 3) adding compressed CO_2; or 4) adding sulfuric acid (H_2SO_4). Mixing of various streams is usually insufficient when the waste is ultimately treated biologically and supplemental chemical addition generally is required for proper pH control. Sulfuric acid is most commonly used to neutralize alkaline waste and sodium hydroxide and sodium carbonate are used to neutralize acidic wastes. Limestone is the cheapest reagent for acidic wastes but is not generally satisfactory for sulfate-bearing wastes because it becomes coated and inactive. If the waste stream is nutrient deficient in either nitrogen or phosphorus, ammonia or trisodium phosphate addition serves the dual purpose of providing both alkalinity and the deficient nutrient.

Industry Application. Current wastewater neutralization practices reported by the textile mills surveyed are summarized in Table VII-6. Essentially the same percentage (21 percent and 19 percent) of direct and indirect dischargers surveyed practice neutralization. Neutralization of acidic waste by indirect dischargers represent the greatest total, which is logical for several reasons. There is a greater total number of indirect dischargers (approximately 80 percent of industry); textile discharges are usually on the acidic side, and most municipalities are apt to be more concerned about acidic discharges than alkaline dischargers. Only a small percentage of both direct and indirect dischargers find it necessary to provide both acidic and alkaline neutralizing capability.

c. Equalization

Industrial discharges that result from a diversity of processes can often be treated more effectively when equalization is practiced as an initial treatment step. This is so because subsequent physical unit operation and chemical and biological unit processes are more efficient if operated at or near uniform hydraulic, organic, and solids loading rates.

TABLE VII-6
WASTEWATER NEUTRALIZATION BY TEXTILE INDUSTRY - RESULTS OF INDUSTRY SURVEY

	Subcategory	Mills Practicing Neutralization							
		Addition of Acid		Addition of Base		Addition of Both		Mills in Survey	
		Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
1.	Wool Scouring	0	0	0	0	0	0	6	2
2.	Wool Finishing	0	0	2	3	1	0	5	10
4.	Woven Fabric Finishing	10	4	2	4	1	0	56	46
5.	Knit Fabric Finishing								
	Fabric Processing	0	1	5	1	0	1	29	42
	Hosiery Processing	0	1	0	1	0	0	2	20
6.	Carpet Finishing	0	0	3	2	0	0	11	24
7.	Stock & Yarn Finishing	3	5	2	7	1	1	29	43
8.	Nonwoven Manufacturing	0	1	0	0	0	1	1	6
9.	Felted Fabric Processing	0	1	0	2	0	2	3	7
	All Subcategories	13	13	14	20	3	5	142	200

Equalization of a variable nature discharge may be accomplished by holding the waste for a period of time corresponding to the repetitive processes of the manufacturing. Thus, facilities that discharge a variable waste over an eight-hour period need to provide up to eight hours of storage. Similar facilities that operate on two or three shifts may need to provide equalization up to a corresponding time period.

The holding basins may be earthen or fabricated from conventional treatment plant construction materials. They may also utilize aerators to enhance mixing.

Industry Application. Current equalization practices reported by the textile mills surveyed are summarized in Table VII-7. A higher percentage of indirect dischargers (46 percent) than direct dischargers (37 percent) provide some form of equalization. This is likely a result of two factors. First, many of the direct discharge mills have extended-aeration activated sludge treatment systems with several days detention time and do not require equalization. Secondly, many of the indirect dischargers are required by the municipalities that treat their waste to equalize their flow. However, a higher percentage of direct dischargers (approximately 15 percent) than indirect dischargers (approximately 4 percent) provide mixed equalization. This is likely a result of the direct dischargers wanting to create a more constant pollutant and hydraulic load for their treatment system and to provide some preliminary biological oxidation.

2. Biological Processes

Biological treatment of industrial wastewater has been practiced for decades on a limited basis, but most activated sludge processes have been constructed in the last 10 to 15 years. It is based on the ability of microorganisms to utilize organic carbon as a food source. The treatment is classified aerobic or anaerobic depending on the presence of free dissolved oxygen. Aerobic biological treatment is accomplished by bacteria (aerobes) that utilize free dissolved oxygen in breaking down (oxidizing) organic carbon. Anaerobic biological treatment is accomplished by bacteria (anaerobes) that utilize "chemically bound" oxygen in breaking down (oxidizing) organic carbon. The distinction is not so clear-cut in real life in that a third class of bacteria (facultative) is also usually active. These bacteria can act as aerobes or anaerobes as the situation dictates, but will always act in a manner yielding the greatest energy.

Unlike municipal wastewater, industrial wastes frequently lack the necessary nutrients to sustain microbial growth. This deficiency can often be overcome by mixing sanitary waste from the plant site with

TABLE VII-7
WASTEWATER EQUALIZATION BY TEXTILE INDUSTRY - RESULTS OF INDUSTRY SURVEY

Subcategory	Unmixed				Mixed				Mills in Survey	
	Direct		Indirect		Direct		Indirect			
	LT 24*	ETGT 24*	LT 24	ETGT 24	LT 24	ETGT 24	LT 24	ETGT 24	Direct	Indirect
1. Wool Scouring	0	0	0	0	0	1	0	0	6	2
2. Wool Finishing	1	0	1	3	1	0	0	0	5	10
4. Woven Fabric Finishing	4	8	19	3	4	5	1	0	56	46
5. Knit Fabric Finishing Fabric Processing	4	3	10	4	2	1	2	1	29	42
Hosiery Processing	0	0	3	4	0	0	0	0	2	20
6. Carpet Finishing	2	1	7	2	0	1	0	0	11	24
7. Stock & Yarn Finishing	3	4	21	5	3	3	1	0	29	43
8. Nonwoven Manufacturing	0	1	2	2	0	0	2	0	1	6
9. Felted Fabric Processing	0	0	0	0	0	0	0	0	3	7
All Subcategories	14	17	63	23	10	11	6	1	142	200

* LT 24 = Less than 24 hours; ETGT 24 = Equal to or greather than 24 hours.

Note:
For four direct discharge mills (two Subcategory 4 and two Subcategory 7) and seven indirect discharge mills (two Subcategory 2, two Subcategory 5 - Fabric Processing, one Subcategory 5 - Hosiery Processing, one Subcategory 6, and 1 Subcategory 7) the equalization detention times could not be calculated, so 24 hours was assumed.

the process waste, or by direct addition of chemicals (nitrogen or phosphorus) containing the proper quantity of deficient nutrients.

A description and discussion of each biological process relevant to the treatment of textile mill wastewaters follows (64).

a. Aerated Lagoons

An aerated lagoon is an aerobic biological process. It is essentially a stabilization basin to which air is added either through mechanical agitation or diffusion. The air provides the necessary oxygen required for aerobic biodegradation of the organic waste. If properly designed, the air addition will provide sufficient mixing to maintain the biological solids in suspension so that they can be removed efficiently in a secondary sedimentation tank. After settling, sludge may be recycled to the head of the lagoon to insure the presence of a properly acclimated seed. When operated in this manner, the aerated lagoon is analogous to the activated sludge process, which is discussed below. The viable biological solids level in an aerated lagoon is low when compared to that of an activated sludge unit. The aerated lagoon relies primarily on detention time for the breakdown and removal of organic matter and aeration periods of 3 to 8 days are common.

Industry Application. Thirty-three direct dischargers and 23 indirect dischargers report using aerated lagoons as part of their treatment systems. Of the direct dischargers, 12 employ aerated lagoons as their primary means of treatment; 14 employ aerated lagoons followed by unaerated aerobic lagoons as their primary means of treatment; 2 employ aerated lagoons as polishing ponds following activated sludge biological treatment; and 6 employ aerated lagoons in combination with advanced treatment (2 chemical coagulaton, 2 filtration, 1 chemical coagulation plus filtration, and 1 activated carbon). Of the indirect dischargers, 21 employ aerated lagoons as their primary pretreatment step, 1 employs an aerated lagoon followed by an unaerated aerobic lagoon, and 1 provides multi-media filtration following an aerated lagoon.

A close inspection of the operating characteristics of the lagoons reported in use reveals that many indirect dischargers may more realistically be providing only mixed equalization. That this is likely is demonstrated by the following tabulation:

Discharge	Number of Mills	hp/mil gal/day Min	Max	Med	Detention Time, hr Min	Max	Med
Direct	9	0.10	1000	38	0.5	2400	75
Indirect	20	5.0	200	600	4	132	24

The 9 direct discharge and 20 indirect discharge mills are those that reported the use of aerated lagoons as their principal treatment or pretreatment component and for which data were available to calculate horsepower application rate and detention time. While the median direct and indirect dischargers provide similar hp/mil gal/day, the median direct dischargers provide more than three times the detention period as the median indirect dischargers. Since detention time is the primary factor in effective operation of an aerated lagoon, it would appear that many of the indirect dischargers are not operating their lagoons as aerated biological lagoons in the true sense.

The effectiveness of aerated lagoons in the treatment of textile wastewater is shown in the following tabulation for those mills that provide wastewater monitoring data. The data reported are the average values for each mill and generally represent that available for 1976.

Sub-category	Dis-charge	hp/ mil gal	Deten-tion, hrs	BOD, mg/l inf	BOD, mg/l eff	COD, mg/l inf	COD, mg/l eff	TSS, mg/l inf	TSS, mg/l eff
4c	Direct	45.0	60	366	94	835	814	-	89
4a	Indirect	400	24	69	69	644	581	54	68
4c	Indirect	780	86	1742	157	-	-	556	599
5a	Indirect	150	18	388	189	1762	1215	-	-
7	Direct	25.0	75	108	14	-	-	21	12
7	Direct	1000	0.5	252	249	556	429	-	110

The tabulation shows that mills providing long detention times are able to effect good removals of BOD. Data are insufficient to project the effectiveness on the removal of COD and TSS.

b. Activated Sludge

The activated sludge process also is an aerobic biological process. The basic components consist of an aerated biological reactor, a clarifier for separation of biomass, and a piping arrangement to return separated biomass to the biological reactor. The aeration requirements are similar to those of the aerated lagoon in that they provide the necessary oxygen for aerobic biodegradation and mixing to maintain the biological solids in suspension.

The activated sludge process is very flexible and can be adapted to many waste treatment situations. Factors that must be considered in design include: 1) loading criteria, 2) reactor type, 3) sludge production, 4) oxygen requirements and transfer, 5) nutrient requirements, 6) environmental requirements, 7) solid-liquid separation, and, 8) effluent characteristics. Depending on these factors, and combinations of these factors, the conventional activated sludge process or standardized modifications of the conventional process can be selected as most appropriate. The available processes that have relevance in the treatment of textile wastewaters include the conventional, complete-mix, tapered-aeration, step-aeration, modified-aeration, contact-stabilization, extended-aeration, oxidation ditch, and pure oxygen.

In the conventional activated sludge process, both influent wastewater and recycled sludge enter the reactor at the head end and are aerated for a period of about 4 to 8 hours. Aeration can be of the diffused or mechanical type and is constant as the mixed liquor moves through the tank in a plug-flow fashion. Oxygen demand decreases as the mixed liquor travels the tank length. The mixed liquor is settled in a conventional clarifier, and the activated sludge is returned at a rate of approximately 25 to 50 percent of the influent flow rate.

In the complete-mix activated sludge process, influent wastewater and recycled sludge enter the reactor from several points along a central channel running the length of the reactor. The mixed liquor is aerated at a constant rate as it passes from the central channel to effluent channels at both sides of the reactor. The contents of the reactor are completely mixed and the oxygen demand remains uniform throughout. The aeration period is from 3 to 5 hours, and the activated sludge is returned at a rate of 25 to 100 percent of influent flow rate.

The tapered-aeration process is a modification of the conventional process, with the arrangement of the aerators and the amount of air supplied the primary differences. At the head of the reactor, where wastewater and returned activated sludge come in contact, more oxygen is required so the aerators are spaced close together. As the mixed liquor traverses the aeration tank, the oxygen demand decreases so aeration is decreased by spacing the aerators further apart. Since the oxygen supply is decreased with the oxygen demand, a lower overall oxygen requirement is a benefit of the tapered-aeration process.

The step-aeration process also is a modification of the conventional activated sludge process. In this modification, the wastewater is introduced at several points in a compartmentized reactor while the return activated sludge is introduced at the head of the reactor. Each compartment of the reactor comprises a separate step, and the several steps are linked together in series. Aeration can be of the diffused or mechanical type and is constant as the mixed liquor moves through the tank in a plug-flow fashion. The demand is more uniformly spread over the length of the reactor than in the conventional activated sludge process, resulting in better utilization of the oxygen supply. The aeration period is typically between 3 and 5 hours, and the activated sludge is returned at a rate of 25 to 75 percent of influent flow rate.

The modified-aeration activated sludge process is like the conventional or tapered-aeration process, except that the aeration period is shorter (usually 1.5 to 3 hours) and the food-to-microorganism ratio higher. Activated sludge is returned at a rate of only 5 to 15 percent of influent flow rate. The resulting BOD removal is approximately 70 percent (for typical sanitary waste), so the process is not suitable where a high-quality effluent is desired.

The contact-stabilization process takes advantage of the absorptive properties of activated sludge by operating the process in two stages. The first is the absorptive phase, in which most of the colloidal, finely suspended, and dissolved organics are absorbed in the activated sludge in a contact tank. The wastewater and return stabilized sludge enter at the head of the contact tank, are aerated for a period of 20 to 40 minutes, and settled in a conventional clarifier. The second is the oxidation phase, in which the absorbed organics are metabolically assimulated providing energy and producing new cells. In this stage the settled sludge from the absorptive stage is aerated for a period of from 3 to 6 hours in a stabilization tank. A portion of the sludge is wasted to maintain a constant mixed liquor volatile suspended solids (MLVSS) concentration in the stabilization tank. Overall aeration requirements are approximately 50 percent of those of the conventional or tapered-aeration plant. However, the process is usually not effective in treating industrial waste in which the organic matter is predominantly soluble.

The extended-aeration process is a complete-mix activated sludge process in which the aeration period is relatively long (24 to 48 hours) and the organic loading relatively low. Because of these conditions, the process is very stable and can accept intermittent loads without upset. In smaller applications, the reactor and clarifier are generally a single-fabricated unit, and all sludge is returned to the reactor. The mixed liquor is allowed to increase in solids concentration over a period of several months and then is removed directly from the aeration basin. In larger applications, the reactor and clarifier are separated and some means of wasting and treating sludge is usually necessary. Reactors can be concrete with diffused aeration or a lined earth basin with mechanical aerators. The extended-aeration activated sludge process is used by the majority of direct dischargers in the textile industry.

The oxidation ditch activated sludge process is an extended-aeration process in which aeration and circulation are provided by brush rotors placed across a race track-shaped basin. The waste enters the ditch at one end, is aerated by the rotors, and circulates at about 1 to 2 fps. Operation can be intermittent, in which case purification takes place in the ditch, or continuous, in which case a separate clarifier and piping for recycling settled sludge are provided.

The pure oxygen activated sludge process is a modification of the complete mix process in which high-purity oxygen, instead of air, is introduced directly into the wastewater. Wastewater, returned activated sludge, and oxygen gas under a slight pressure are introduced at the head of an aeration tank that is divided into stages by a means of baffles and covered with a gas-tight enclosure. Oxygen may be mixed with the mixed liquor by recirculation through a hollow shaft with a rotating sparger device or by surface mechanical aerators. The mixed liquor passes from compartment to compartment and is discharged from the last compartment to a clarifier. Waste gas, which is a mixture of carbon dioxide, nitrogen, and 10 to 20 percent of the oxygen applied, is exhausted in the last compartment. Reported advantages of the pure oxygen process are high efficiency, decreased sludge volume, reduced aeration tank volume, and improved sludge settleability.

Industry Application. Ninety-four direct dischargers and 11 indirect dischargers report using activated sludge as part of their treatment systems. Of the direct dischargers, 55 employ activated sludge as their primary means of treatment; 24 employ activated sludge followed by unaerated lagoons; 3 employ activated sludge followed by chemical coagulation; 4 employ activated sludge with chemical addition to the activated sludge effluent to aid in settling; 4 employ activated sludge followed by filtration; 2 employ activated sludge followed by aerated lagoons; 1 employs activated sludge followed by filtration and aeration lagoons, and 1 employs activated sludge followed by a trickling filter. Of the indirect dischargers, 9 employ activated sludge as the primary means of pretreatment, while 2 other mills employ activated sludge followed by chemical coagulation.

The effectiveness of activated sludge in treating textile wastewater is demonstrated in the following tabulation for those mills that have reported historical monitoring data. The data reported are the average values for each mill and generally represent that available for the year 1976.

Sub-category	Dis-charge	hp/ mil/gal	Deten-tion*, hrs	BOD, mg/l inf	BOD, mg/l eff	COD, mg/l inf	COD, mg/l eff	TSS, mg/l inf	TSS, mg/l eff
1	Direct	160	99	1563	125	16250	2600	3971	1231
4c	Direct	120	106	475	19	-	-	-	91
4a	Direct	60	24	133	22	472	307	34	38
4c	Direct	41	75	267	24	840	336	-	27
4c	Direct	58	131	400	8	-	252	80	8
4c	Direct	250	97	329	23	2970	594	-	44
4c	Direct	80	78	640	105	1240	664	173	176
4a	Direct	60	120	180	9	468	159	26	18
4b	Direct	90	80	250	5	-	-	218	48
5b	Direct	60	48	272	45	694	354	28	55
5a	Direct	74	82	190	19	342	164	97	63
5a	Direct	40	417	198	13	745	226	49	62
5b	Direct	75	110	181	5	-	124	18	18
5b	Direct	160	76	1100	11	-	262	281	45
6	Direct	44	130	207	29	614	227	93	50
7	Direct	80	33	150	6	496	124	36	27
7	Direct	500	44	1631	233	4756	1844	136	195
7	Direct	80	50	125	5	-	158	46	21

* Calculated based on average flow and basin volume.

All the mills listed are operating their activated sludge systems in the extended-aeration mode and employ surface aerators for mixing and oxygenation. Many of the actual detention periods noted are much longer than those used in design because they are calculated based on present average flow conditions and full basin volumes. Also, solids may settle in aeration basins, resulting in shorter detention periods. Removals range from excellent to somewhat poor for BOD and COD; for TSS, removals are generally poor or solids increase due to generation of biomass. The effectiveness of the extended-aeration activated sludge process in treating priority pollutants is discussed in Section V.

c. Biological Beds

Biological beds are fixed-growth biological systems that contact wastewater with microbial growths attached to the surfaces of supporting media. Systems that are in common use include trickling filters, packed towers, and rotating biological disks. While the physical structures differ, the biological process is essentially the same in all of these systems.

As wastewater contacts the supporting media, a thin-film biological slime develops and coats the surfaces. The film consists primarily of bacteria, protozoa, and fungi that feed on the waste. Organic matter and dissolved oxygen are extracted and the metabolic end products are released. Although very thin, the biological slime layer is anaerobic at the bottom so hydrogen sulfide, methane, and organic acids are generated. These materials cause the slime to periodically separate (slough off) from the supporting media and it is carried through the system with the hydraulic flow. The sloughed biomass must be removed in a clarifier.

Trickling filters are classified by hydraulic or organic loading as low-or high-rate. Low-rate filters generally have a hydraulic loading rate of 1 to 4 mil gal/acre/day, an organic loading rate of 300 to 1000 lb BOD_5/acre-ft-day, a depth of 6 to 10 feet, and no recirculation. High-rate filters have a hydraulic loading rate of 10 to 40 mil gal/acre/day, an organic loading rate of 1000 to 5000 lb BOD_5/acre-ft-day, a depth of 3 to 10 feet, and a recirculation rate of 0.5 to 4. High-rate filters can be single- or two-stage. The most suitable media in both the low- and high-rate filters is crushed stone, or gravel, graded to a uniform size within the range of 1 to 3 inches. The material must be strong and durable.

Biological towers are much like conventional trickling filters but with manufactured media instead of crushed rock or gravel media. The manufactured media can be corrugated plastic packing or rough-sawn redwood slats, both of which are very effective in retaining biological films. The advantages of this type of media are a high specific surface (sq ft/cu ft), a high percentage of void volume, uniformity for better liquid distribution, light weight facilitating construction of deeper beds, chemical resistance, and the ability to handle high-strength and unsettled wastewaters. Biological towers can be used in flow patterns similar to normal high-rate natural-media filter systems. For strong waste, two towers may be set in series and settled solids from the final clarifier can be returned to the first tower influent. Because of the increased void space, activated sludge will build up in the flow and the system will perform as both a filter, with fixed biological growth, and as a mechanical aeration system. Biological beds generally have a hydraulic loading rate of up to 2 gpm/sq ft, an organic loading rate of from 25 to 150 lb BOD_5/1000 cu ft/day, and a depth of 20 feet.

The rotating biological disk makes use of the advantages of the manufactured plastic media used in the packed tower to increase the contact time between the wastewater and fixed biological growth. A series of disks constructed of corrugated plastic plate and mounted on a horizontal shaft are placed in a contour-bottomed tank and immersed to approximately 40 percent of the diameter. The disks rotate as wastewater passes through the tank and a fixed film biological growth, similar to that on trickling filter media, adheres to the surface. Alternating exposure to the wastewater and the oxygen in the air results in biological oxidation of the organics in the wastes. Biomass sloughs off, as in the trickling filter and packed tower systems, and is carried out in the effluent for gravity separation. Direct recirculation is not generally practiced with the rotating biological disks.

Industry Application. Currently, there are only there textile mills that utilize biological beds in their wastewater treatment systems. Two systems are trickling filters and both mills employing them are direct discharge woven fabric finishers. One of these mills uses a somewhat modified approach to the standard filtration process. The beds are square, 14 to 16 feet deep, wastewater is applied continuously, and forced ventilation insures aerobic conditions throughout. The system obtains a very efficient 96 percent BOD_5 reduction. The other mill employs a standard high-rate trickling filter as a polishing process after activated sludge treatment. The overall system performance effects a 98 percent BOD_5 and 93 percent COD removal. The third mill employs a rotating biological disk as an intermediate step between filtration and biological aeration. This mill is a direct discharger and practices recovery of dyestuff.

d. Stabilization Lagoons

Stabilization lagoons are rather popular biological treatment processes. They are often called lagoons or oxidation ponds and are classified aerobic, facultative, tertiary (polishing), and anaerobic. They are used extensively in the treatment of municipal waste in small communities and in the treatment of some industrial and industrial-municipal wastes that are amendable to biological treatment.

Aerobic lagoons contain bacteria and algae in suspension, and aerobic conditions prevail throughout the depth. Waste is stabilized as a result of the symbiotic relationship between aerobic bacteria and algae. Bacteria break down waste and generate carbon dioxide and nutrients (primarily nitrogen and phosphorus). Algae, in the presence of sunlight, utilize the nutrients and inorganic carbon; they in turn supply oxygen that is utilized by aerobic bacteria. Aerobic lagoons are usually less than 18 inches deep (the depth of light penetration) and must be periodically mixed to maintain aerobic conditions throughout. In order to achieve effective removals with aerobic lagoons, some means of removing algae (coagulation, filtration, multiple cell design) is necessary. Algae have a high degree of mobility and do not settle well using conventional clarification.

In facultative lagoons, the bacterial reactions include both aerobic and anaerobic decomposition. The symbiotic relationship between aerobic bacteria and algae exist, as in aerobic lagoons, and anaerobic decomposition takes place by bacteria that feed on settled solids. Facultative lagoons are up to 5 feet in depth and require the same types of provisions for removing algae if effective pollutant removals are to be realized. Most of the textile mills reporting use of stabilization lagoons are operating facultative lagoons.

Tertiary lagoons serve as a polishing step following other biological treatment processes. They are often called maturation or polishing ponds and primarily serve the purpose of reducing suspended solids. Water depth is generally limited to 2 or 3 feet and mixing is usually provided by surface aeration at a low power-to-volume ratio. Tertiary lagoons are quite popular as a final treatment step for textile wastewater treated with the extended-aeration activated sludge process.

Anaerobic lagoons are anaerobic throughout their depth and have the advantage of a low production of waste biological sludge and low operating costs. Stabilization is brought about by a combination of precipitation and anaerobic decomposition of organics to carbon dioxide, methane, other gaseous end products, organic acids, and cell tissue. Lagoons are constructed with depths up to 20 feet and steep side walls to minimize the surface area relative to total volume. This allows grease to form a natural cover, which retains heat, suppresses odors, and maintains anaerobic conditions. Wastes enter near the bottom and the discharge is located on the opposite end below the grease cover. Sludge recirculation is not necessary because gasification and the inlet-outlet flow pattern provides adequate mixing. The anaerobic lagoon is not particularly suitable for treating textile wastewaters, with the possible exception of wool scouring waste.

Industry Application. Current utilization of stabilization lagoons by the textile mills surveyed is summarized in Table VII-8. Forty-four direct dischargers and 17 indirect dischargers report using stabilization lagoons as part of their treatment system. Of the direct dischargers, 3 employ facultative lagoons as their primary means of treatment; 15 employ facultative lagoons following aerated lagoons; 25 employ tertiary lagoons following activated sludge; and one employs a tertiary lagoon after activated sludge and prior to chemical coagulation. Of the indirect dischargers, 15 employ facultative lagoons as their primary means of treatment; 1 employs a facultative lagoon following an aerated lagoon, and 1 employs two parallel anaerobic lagoons prior to activated sludge.

Only one mill reported both influent and effluent monitoring data for the lagoon portion of their treatment system. However, several of the mills employing facultative lagoons as their primary treatment, or pretreatment, provided effluent data that can be used to give an indication of the effectiveness. These data are presented in the following tabulation.

TABLE VII-8

USE OF STABILIZATION LAGOONS BY TEXTILE INDUSTRY INDUSTRY - RESULTS OF INDUSTRY SURVEY

Subcategory	Facultative Lagoon		Aerated Lagoon + Facultative Lagoon		Activated Sludge + Tertiary Lagoon	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
1. Wool Scouring	0	2	0	0	1	0
2. Wool Finishing	0	0	2	0	0	0
4. Woven Fabric Finishing	2	3	3	0	11	0
5. Knit Fabric Finishing Fabric Processing	0	7	3	0	5*	1
Hosiery Processing	0	2	0	0	0	0
6. Carpet Finishing	0	0	3	0	2	0
7. Stock & Yarn Finishing	0	2	4	1	5	0
8. Nonwoven Manufacturing	1	1	0	0	1	0
9. Felted Fabric Processing	0	0	0	0	0	0
All Subcategories	3	17	15	1	25	1

* One mill follows tertiary lagoon with chemical coagulation.

Subcategory	Discharge	Effluent Concentration, mg/l BOD	COD	TSS
4c	Direct	53	175	14
4c	Direct	35	115	35
4b	Indirect	482	2186	18
5b	Indirect	325	810	40
5b	Indirect	145	-	-
5a	Indirect	141	862	-
5c	Indirect	211	548	-
7	Indirect	233	634	59
7	Indirect	111	789	945
8	Direct	17	-	29
8	Indirect	79	-	179

Literature/Research. Although a number of textile mills utilize tertiary lagoons as a final treatment step (see Industry Application), there are few historical data available that can be used to demonstrate the effectiveness of the lagoons in treating conventional, non-conventional, and toxic pollutants. Sampling was conducted around the polishing lagoons at two mills during this study. The results are summarized in the following cases.

Case 1

This case discusses the results at a Subcategory 7 Stock & Yarn Finishing facility that dyes stock (approximately 33 percent of production) and yarn (approximately 67 percent of production) of wool, nylon, and acrylic fibers. Production is reported to average 31,750 kg/day (70,000 lb/day), with a water usage and wastewater discharge of 90 l/kg (10.7 gal/lb) and 2,840 cu m/day (0.75 mgd), respectively.

Wastewater treatment at this facility consists of fine screening (stationary), equalization (mixed with a power-to-volume ratio of 50 hp/mil gal), aeration (one basin with a volume of 1 mil gal), secondary clarification, effluent polishing (parallel primary and secondary oxidation ponds with a total volume of 15 mil gal), and disinfection (chlorine). Aeration detention time is approximately 24 hours, and air is provided by surface aerators at a power-to-volume ratio of 150 hp/mil gal.

Samples were collected (see Appendix D for sampling procedures) over a typical 24-hour period of operation at the influent to the aeration basin, at the effluent of the secondary clarifier, and at the chlorine contact chamber. The results presented below demonstrate the effectiveness of the polishing ponds in treating conventional, non-conventional, and toxic pollutants.

Conventional and Non-Conventional Pollutant Treatability
Influent and Effluent to Polishing Pond

Parameter	Influent	Effluent
COD, mg/l	78	142
TSS, mg/l	37	28
Phenols, ug/l	36	51
Sulfide, ug/l	2	ND
Color, ADMI	208	218

ND not detected

Toxic Pollutant Treatability
Influent and Effluent to Polishing Pond

Toxic Pollutant	Influent, ug/l	Effluent, ug/l
Trichlorofluoromethane	48	ND
Bis(2-ethylhexyl) Phthalate	40	11
Lead	36	ND
Zinc	865	123

ND not detected

The following pollutants were detected at less than 10 ug/l in the secondary clarifier effluent and the final effluent: 2,4-Dichlorophenol; Phenol; Di-n-butyl Phthalate; Toluene; Arsenic; Chromium; Copper, Silver.

Case 2

This case discusses the results at a Subcategory 9 Felted Fabric Processing facility that manufactures papermakers wet felts and dryer felts. Processing operations include weaving, scouring, fulling, and functional finishing. Production at this facility is reported to average 2,100 kg/day (approximately 4,600 lb/day), and the facility has a water usage and wastewater discharge of 116.6 l/kg (14 gal/lb) and 378.5 cu m/day (0.10 mgd), respectively.

Wastewater treatment at this facility consists of equalization (mixed with a power-to-volume ratio of 50 hp/mil gal), aeration (one basin with a volume of 1 mil gal), secondary clarification, effluent polishing (one basin with a volume of 2.5 mil gal), disinfection (chlorine), and land application (spray). Aeration detention time is approximately 160 hours, and air is provided by surface aerators at a power-to-volume ratio of 60 hp/mil gal.

Samples were collected (see Appendix D for sampling procedures) over a typical 24-hour period of operation at the influent to the equalization basin, after the secondary clarifier, and following the polishing pond. The results presented below demonstrate the effectiveness of the polishing pond in treating conventional, non-conventional, and toxic pollutants.

Conventional and Non-Conventional Pollutant Treatability
Influent and Effluent to Polishing Pond

Parameter	Influent	Effluent
COD, mg/l	552	263
TSS, mg/l	91	22
Phenols, ug/l	52	28
Sulfide, ug/l	ND	ND
Color, ADMI	283	303

ND not detected

Toxic Pollutant Treatability
Influent and Effluent to Polishing Pond

Toxic Pollutant	Influent, ug/l	Effluent, ug/l
Naphthalene	56	ND
Bis(2-ethylhexyl) Phthalate	18	ND
Chromium	35	ND
Copper	ND	18
Selenium	32	18
Zinc	45	101

ND not detected

The following pollutants were detected at less than 10 ug/l in the secondary clarifier effluent and the final effluent: Phenol; Toluene.

3. Chemical Processes

a. Coagulation

Suspended solids are a significant constituent of most textile mill wastewaters. The larger solids are removed in preliminary treatment steps but a variety of colloidal particulates remain even after secondary treatment. Besides fiber, these solids include color bodies, soaps, mineral fines, oil & grease, and microscopic organisms. The wastewater from carpet mills, other adhesive-related processing mills, and nonwoven processing facilities may, in addition, contain considerable amounts of latex. In excess, these pollutants are not suitable for discharge to receiving waters and can upset tertiary treatment processes or result in inefficient operation of these processes. Coagulation often can be employed to remove these pollutants.

Coagulation is the process by which chemicals are employed to destabilize suspended material such that the particles contact and agglomerate. The forces that act to keep small particles apart and hence lead to a stable, colloidal suspension are hydration, which results in a protective shell of water molecules, and electrostatic charge. Most colloidal particles carry a characteristic negative charge and are thus unable to coalesce due to this electrostatic repulsion. Neutralization of these repulsive forces by the addition of multivalent cations enables the particles to come together and thus settle out (64).

The most effective inorganic coagulants for wastewater treatment are alum (aluminum sulfate), copperas (ferrous sulfate), lime (calcium hydroxide), ferric chloride, and ferric sulfate. The multivalent cations, Al^{+3}, Fe^{+3}, and Fe^{+2} enter into a series of hydrolytic reactions to form multivalent positively charged hydrous oxide species that are adsorbed onto the negatively charged colloid. This neutralizes the colloidal system and allows the particles to agglomerate.

Since these chemical reactions are virtually instantaneous, a rapid mix process is used to mix the coagulant with the wastewater. This brief mixing provides a complete dispersion of the coagulant throughout the wastewater but is not long enough for agglomeration to take place. The second stage of the process, flocculation, promotes inter-particle contact of the stabilized colloids to form a floc that is, in turn, removed in the final stage of the process, sedimentation.

In addition to the coagulants noted, polyelectrolytes (polymers) may be used as coagulant aids or as the sole coagulant. These compounds contain repeating units of small molecular weight, combined to form a molecule of colloidal size. Each of the repeating units carries one or more electrical charges or ionizable groups. Because of their large size, the major benefit of polyelectrolytes is an increase in floc size. It is generally agreed that a "bridging" mechanism is responsible for flocculation enhancement. One end of the polymer molecule attaches itself to the surface of a suspended particle at one or more sites and the free end is able to adsorb onto yet another suspended particle forming a "bridge" between the two. This union increases the mass of the colloidal-polymer system and increases the settling velocity. As the particle settles, it entraps other colloids and polymers and thus clarifies the wastewater with a "sweep floc" effect.

Industry Application. Thirty-four of the wet-processing mills surveyed report that chemical coagulation is employed in their waste treatment systems. Sixteen of these mills are direct dischargers, 15 are indirect dischargers, 2 practice complete recycle, and 1 discharges to an evaporation lagoon after coagulation. At 13 mills, the primary or only portion of the flow treated by coagulation is latex or print waste; all but 3 of these are indirect dischargers, and this accounts for two-thirds of all the indirect discharge mills that identify coagulation as part of their treatment system. Of the direct dischargers employing coagulation for treatment of wastewater other than latex or print wastes, 2 employ it as a last step after biological treatment, 6 add polymer and/or alum to the effluent from an aeration basin prior to secondary sedimentation, 2 coagulate as an intermediate step between activated sludge and filtration, and 2 coagulate in place of biological treatment. At 2 mills, the information was insufficient to place the treatment accurately.

Based on the above breakdown, there are only 2 mills that are presently treating integrated textile wastewater using coagulation as their principal treatment process and 6 mills (4 direct dischargers and 2 recycle) that employ coagulation as a tertiary treatment measure. However, because of the nature of the historical data available from these mills, i.e., influent and effluent data for the entire treatment systems, the effectiveness of the chemical coagulation process alone cannot be demonstrated. The following tabulation does demonstrate the overall effectiveness of the treatment systems that include coagulation. The data represent average values for those mills that provide historical monitoring results and generally represent sampling during 1976.

Subcategory	Coagulants	Treatment Step	BOD, mg/l Inf	BOD, mg/l Eff	COD, mg/l Inf	COD, mg/l Eff	TSS, mg/l Inf	TSS, mg/l Eff
		(Direct Dischargers)						
2	Alum, Polymer	Secondary Clarifier	150	11	900	-	175	64
4b	Alum	Secondary Clarifier	83	14	308	152	43	35
4b*	-	Flotation Unit	-	51	-	482	-	188
4c	-	Secondary Clarifier	200	51	845	663	82	142
4c	Polymer	Secondary Clarifier	-	7	846	164	-	54
4c*	Ferric Chloride, Lime	Coag/Floc Raw Waste	-	4	1400	99	168	30
4c*	-	-	760	12	1600	248	420	99
5a	-	Coag/Floc Secondary	334	24	1265	206	-	40
5a	Polymer	Secondary Clarifier	-	24	-	272	-	65
5a	Polymer	Injection Pre-Filtration	279	5	934	196	41	7
7	Alum, Polymer	Secondary Clarifier	327	20	1572	480	26	23
7	Chlorinated Copperas, Lime	Secondary Clarifier	60	15	331	129	31	11
8	-	Flotation Post-Biological	-	6	-	-	-	14

(Indirect Dischargers)

2	Lime	Coag/Floc Raw Waste	-	-	1328	556	-	560
4a*	Lime, Alum	Flotation	-	250	-	400	-	30
4c*	Ferric Chloride	Coag/Clarify Print Waste	-	420	-	695	-	118
4a**	Aluminum Chloride	Flotation Print Waste	-	341	-	885	-	206
4a*	Alum	Coag/Clarify Print Waste	322	126	1985	263	460	72
		(Recycle Plant)						
4a*	Alum	Flotation	298	10	-	1550	-	5

* Fabric printing is a significant portion of production.
** Latex and PVC coating operation.

Literature/Research. Coagulation of textile wastewaters has received considerable attention by the engineering and research communities. Much of the work is general and does not address adaptability to textile dischargers. Some of the studies are too specific and would not be generally applicable. The following cases offer relevant information on studies that appear to be both adaptable and generally applicable.

Case 1

This case presents the results of a laboratory study (65) performed in 1974 to evaluate the effectiveness of coagulation using alum in removing color from a dyehouse effluent. The effluent was from a Woven Fabric Finishing mill that processes cotton-polyester broadwoven fabrics. The types of processing performed and the types of dye utilized were not provided by the author.

The mill's dyehouse wastewater, boiler blowdown, and air conditioning condensate were being treated in a two-stage aerated lagoon. Approximately 50 percent removal of BOD was being achieved prior to discharge to a small creek.

The study utilized a jar test apparatus to conduct a series of coagulation investigations using various dosages of alum. The results are presented below and establish the feasibility of removing COD and color from the dyehouse wastewater prior to biological treatment.

Alum Dosage, mg/l as $Al_2(SO_4)_3\text{-}18H_2O$	Total COD, mg/l inf*	eff**	Soluble COD, mg/l inf	eff	TSS, mg/l inf	eff	Color, APHA inf	eff
660	935	490	582	429	132	49	12,800	580
660	903	471		-		-	10,200	288
550	1,590	598	667	559	590	12	8,800	428
440	1,030	525	730	335		-	7,700	450
440	973	590		-		-	11,000	442
440	954	573	740	519		-	12,200	340
330	805	398		-		-	11,800	690

* "inf" represents dyehouse effluent
** "eff" represents supernatant from jar test after 1 hr settling

Case 2

This case presents the results of a laboratory study (66) performed to evaluate the effectivness of coagulation of textile mill printing waste. The waste studied was collected from the discharge line of the printing department of a large Subcategory 4c Woven Fabric Finishing facility. The facility dyes and/or prints sheets, and the waste streams resulting from the dyeing and printing operations are segregated. At the time of the investigation, the waste from the printing department contained printing pigment, adhesives, an acrylic latex emulsion, and varsol (print paste carrier). These constituents are typically suspended in the waste in particulate or colloidal form and are not readily solubilized by microorganisms when subjected to biological treatment.

Samples of the waste stream were subjected to a series of jar test experiments using the following coagulants: ferric chloride, ferric sulfate, and aluminum sulfate. The experiments reported here consisted of placing a one-liter sample into a standard flocculation vessel and stirring at 100 rpm, adding the desired quantity of coagulant and adjusting the pH with HCl or NaOH, mixing for 1 minute after pH adjustment at 100 rpm and flocculating for 2 minutes at 10 rpm, and quiescent settling for 30 minutes followed by analysis. Results are presented below and establish the feasibility of removing the suspended and colloidal materials.

Coagulant	Dosage, mg/l of Metal+3	pH	Turbidity, JTU inf	eff	COD, mg/l inf	eff
Ferric Chloride	25	6.6	270	19	2,100	665
Ferric Sulfate	25	7.1	270	26	2,100	155
Aluminum Sulfate	25	6.6	270	14	2,100	235

Case 3

This case presents a summary of the results of a full scale investigation (24) of activated sludge and alum coagulation treatment of the wastewater from a Subcategory 5a Knit Fabric Finishing mill. The investigations were supported by an EPA Demonstration Grant, and were conducted over a 1 year period.

At the time of the study, the mill was producing velour fabric for the apparel trade (approximately 56 percent), nylon fabric for the automotive industry (approximately 13 percent), fabric of polyester/nylon blends for the uniform trade (approximately 13 percent), and various other fabrics each at less significant production levels.

During the study period, the mill's daily production ranged from a low monthly average of approximately 14,790 kg (34,000) lbs to a high monthly average of approximately 24,800 kg (57,000) lbs. Average daily production was approximately 20,900 kg (48,000 lbs). The production was pressure beam-dyed (approximately 54 percent), atmospheric beck-dyed (approximately 27 percent), or pad-dyed (approximately 17 percent). Approximately 30 percent of the dyestuff utilized was of the disperse class and 20 percent was of the acid class. Besides dyeing, the production was scoured and various functional finishes (water repellents, softeners, and flame retardants) were applied.

The wastewater treatment system, as studied, included heat reclamation, equalization, activated sludge (aerated lagoon plus clarifier), alum coagulation, chlorination, and mechanical sludge processing (horizontal scroll centrifuge). The performances of each component of the treatment system were studied and evaluated. The following tabulation presents the performance of the alum coagulation component throughout the study period for the parameters of primary concern here.

Parameter	Influent (yearly median)*	Effluent (yearly median)*
BOD, mg/l	122	33
COD, mg/l	1,056	416
TOC, mg/l	200	105
TSS, mg/l	368	122
Dissolved Solids, mg/l	619	600
Phenols, ug/l	30	40
Color, APHA	804	320
Chromium, ug/l	360	280
Copper, ug/l	30	ND
Lead, ug/l	28**	23**
Nickel, ug/l	10**	10**
Zinc, ug/l	220	110
Mercury, ug/l	1.8**	1.7**

* Samples were collected daily and daily analysis were performed for all parameters listed except phenolics and metals; the samples for these parameters were composited and analyzed once per month.

** average values

ND not detected

EPA/Industry Field Studies. In a joint research effort between EPA and the textile industry (ATMI, NTA, and CRI), pilot plant studies were conducted during 1977 and 1978 at 19 textile mills to evaluate the effectiveness of alternative advanced wastewater treatment technologies. The studies were performed on the effluent from treatment systems employing the recommended BPT level of treatment. One of the alternatives was chemical coagulation using a 1,650 gallon reactor/clarifier. Prior to initiating the pilot plant studies, jar testing was performed to determine the coagulant(s) and dosage(s) most effective for removal of TSS and organic material. Among the coagulants evaluated were alum, ferric chloride, polymers, and lime, both alone and in various pairings. These jar tests determined operating conditions for the reactor/clarifier during screening (comparison) experiments against other tertiary process modes. Based on these comparisons, promising modes were selected to be studied more extensively in candidate process evaluations. The effectiveness of precoagulation on filtration effectiveness was also studied, but these experiments are discussed under "Filtration." The available results of the coagulation studies during the candidate process evaluations are discussed in the following cases.

Case 1

This case discusses the results at Mill D, a Subcategory 4c Woven Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

The experimental testing was performed on secondary clarifier effluent prior to chlorination. However, such high coagulant dosages (150 mg/l as Al^{+3} with lime at 200 mg/l) were required during jar test studies to achieve even partial TSS reduction, that no pilot scale experiments using the reactor/clarifier were run.

Case 2

This case discusses the results at Mill B, a Subcategory 2 Wool Finishing mill. A description of the manufacturing operations and wastewater treatment of this mill is provided in Appendix F.

Secondary clarifier effluent prior to chlorination was used in the pilot plant tests at this mill. The experimental runs during the candidate mode operation utilized the reactor/clarifier unit for coagulation as the first treatment process. Data on the effectiveness of the unit are presented below.

Conventional and Non-Conventional Pollutant Treatability at Mill B
Influent and Effluent to Reactor/Clarifier*

Pollutant	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	130	50	9	27	14	9
COD, mg/l	827	447	9	229	5	9
TSS, mg/l	122	67	9	33	36	9
TOC, mg/l	236	103	6	76	28	6

* Loading rate of 400 gpd/ft^2 with 5 mg/l alum (as Al^{+3}) added as the coagulant (9/6 - 9/13/77, low underflow rate).

$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill B
Influent and Effluent to Reactor/Clarifier*

Pollutant	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD5, mg/l	212	58	9	39	13	9
COD, mg/l	1161	192	9	194	68	9
TSS, mg/l	352	118	9	6	6	9
TOC, mg/l	398	98	9	68	29	9

* Loading rate of 400 gpd/ft² with 35 mg/l alum (as Al^{+3}) added as the coagulant (9/16 - 9/21/77, increased underflow rate).
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Polltant Treatability at Mill B
Influent and Effluent to Reactor/Clarifier*

Pollutant	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD5, mg/l	248	-	1	17	-	1
COD, mg/l	769	170	3	216	137	3
TSS, mg/l	289	128	3	82	86	3
TOC, mg/l	260	50	3	77	45	3

* Loading rate of 520 gpd/ft² with 27 mg/l alum (as Al^{+3}) added as the coagulant.
$\bar{x}$ mean
SD standard deviation
n number of samples

In addition to the regular pilot plant studies at this facility, samples were collected over a 24-hr period to evaluate the effectiveness of the candidate mode in treating toxic pollutants. The candidate mode tested included the reactor/clarifier followed by multi-media filtration followed by carbon adsorption. The reaction/clarifier was loaded at a rate of 400 gpd/ft² with 35 mg/l alum as (Al^{+3}) added as a coagulant, the multi-media filter was loaded at a rate of 5.4 gpm/ft², and the carbon columns were operated at an empty bed retention time of 25 to 30 minutes. Data on the effectiveness of the reactor/clarifier are presented below.

Toxic Pollutant Treatability at Mill B
Influent and Effluent to Reactor/Clarifier

Toxic Pollutant	Influent, ug/l	Effluent, ug/l
1,2,4-Trichlorobenzene	1580	154
1,2-Dichlorobenzene	20	not detected
Bis(2-ethylhexyl) Phthalate	32	44
Toluene	31	14
Antimony	22	23
Arsenic	60	62
Chromium	116	41
Copper	23	16
Lead	30	30
Nickel	76	57
Silver	140	172
Zinc	6400	5730

The following pollutants were detected at less than 10 ug/l in the influent and effluent: Ethylbenzene, Phenol.

Case 3

This case discusses the results at Mill Q, which is actually two separate Subcategory 5 Knit Fabric Finishing mills that discharge to a common waste treatment plant. A description of the manufacturing operations and wastewater treatment at this complex is provided in Appendix F.

Secondary clarifier effluent prior to chlorination was used in the pilot plant tests at this mill. The experimental runs during the candidate mode of operation utilized the reactor/clarifier unit as the first treatment process. Data on the effectiveness of this process for treating conventional and non-conventional pollutants are presented below.

Conventional and Non-Conventional Pollutant Treatability at Mill Q
Influent and Effluent to Reactor/Clarifier*

Pollutant	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	7.4	2.6	7	5.4	1	7
COD, mg/l	254	39	7	195	78	7
TSS, mg/l	50	16	7	73	14	7
TOC, mg/l	-	-	-	-	-	-
Color, ADMI	227	44	6	202	19	6

* Loading rate of 400 gpd/ft² with 20 mg/l alum (as Al^{+3}) and 0.75 mg/l anionic polymer added as the coagulants (Experiment 1).
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill Q
Influent and Effluent to Reactor/Clarifier*

Pollutant	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	8.6	1	5	2.9	1.5	5
COD, mg/l	278	15	5	173	51	5
TSS, mg/l	39	4	5	57	34	5
TOC, mg/l	-	-	-	-	-	-
Color, ADMI	150	32	3	209	132	3

* Loading rate of 320 gpd/ft² with 30 mg/l alum (as Al^{+3}) and 1.0 mg/l anionic polymer added as the coagulants (Experiment 2).
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill Q
Influent and Effluent to Reactor/Clarifier*

Pollutant	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	8.5	2.2	5	4.6	3.7	5
COD, mg/l	283	19	5	182	77	5
TSS, mg/l	45	7.2	5	66	58	5
TOC, mg/l	30.3	14	4	21.5	10	4

* Loading rate of 320 gpd/ft^2 with 30 mg/l alum (as Al^{+3}) and 1.0 mg/l anionic polymer added as the coagulants (Experiment 2).
$\bar{x}$ mean
SD standard deviation
n number of samples

In addition to the regular pilot plant studies at this facility, samples were collected on two consecutive days to evaluate the effectiveness of the pilot plant technologies in removing toxic pollutants. One mode of operation tested was the reactor/clarifier followed by the multi-media filters. The reactor/clarifier was operated at a surface loading rate of 320 gpd/ft^2, with coagulant dosages of 30 mg/l alum and 1.0 mg/l anionic polymer. The multi-media filters were loaded at a rate of 3 gpm/ft^2. Data on the effectiveness of this mode of treatment are presented below. The data are presented here because it is expected that the coagulation process, rather than the multi-media filtration step, is most responsible for toxic pollutant removals.

Toxic Pollutant Treatability at Mill Q
Influent and Effluent to Reactor/Clarifier - Multi-Media Filter*

Toxic Pollutant	Influent** Min	Max	n	Effluent** Min	Max	n
Bis(2-ethylhexyl) Phthalate	-	15	1#	-	7	1#
Antimony	660	680	2	620	670	2
Chromium	27	36	2	14	15	2
Copper	100	110	2	90	92	2
Lead	-	48	1	46	53	2
Selenium	20	62	2	10	110	2
Silver	-	13	1	9.4	12	2
Zinc	47	50	2	130	190	2

* Samples collected around candidate mode of operation; each sample represents 24-hour composite
** Concentrations in ug/l
# Composite sample collected over 48-hour period
n number of sample

The following were detected at less than 10 ug/l in the influent and effluent: 2,4,6-Trichlorophenol; 2-Nitrophenol.

Case 4

This case discusses the results at Mill V, a Subcategory 4c Woven Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

Secondary clarifier effluent prior to chlorination was used in the pilot plant tests at this mill. The experimental runs during the candidate mode of operation utilized the reactor/clarifier unit as the first treatment process. Data on the effectiveness of this process for removing conventional and Non-Conventional pollutants are presented below.

Conventional and Non-Conventional Pollutant Treatability at Mill V
Influent and Effluent to Reactor/Clarifier*

Pollutant	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD5, mg/l	9.3	8.5	14	3.6	2	14
COD, mg/l	393	110	14	352	35	14
TSS, mg/l	47	89	14	51	17	14
TOC, mg/l	76	11	14	72	9	14
Color, ADMI	247	43	13	274	57	13

* Loading rate of 400 gpd/ft^2 with 40 mg/l alum (as Al^{+3}) added as the coagulant.
$\bar{x}$ mean
SD standard deviation
n number of samples

In addition to the regular pilot plant studies at this facility, samples were collected over a 24-hour period to evaluate the effectiveness of the candidate mode in removing toxic pollutants. The mode included the reactor/clarifier, multi-media filters, and activated carbon columns. The reactor/clarifier was operated at a surface loading rate of 400 gpd/ft^2 with a coagulant dosage of 40 mg/l alum (as Al^{+3}). The multi-media filters were loaded at a rate of 3.0 gpm/ft^2, and the carbon columns were operated at 0.46 gpm (empty bed retention time of 45 minutes). Data on the effectiveness of the reactor/clarifier are presented below.

Toxic Pollutant Treatability at Mill V
Influent and Effluent to Reactor/Clarifier

Toxic Pollutant	Influent, ug/l	Effluent, ug/l
1,2-Dichlorobenzene	not detected	13
Bis(2-ethylhexyl) Phthalate	8	34
Toluene	15	trace
Antimony	96	123
Chromium	trace	17
Copper	57	10
Lead	27	66
Silver	80	72
Zinc	163	195

The following were detected at less than 10 ug/l in the influent and effluent: 1,4-Dichlorobenzene; Ethylbenzene; Chlorodibromomethane; Pentachlorophenol; Phenol; Di-n-butyl Phthalate; Anthracene; Arsenic, Cadmium, Nickel.

Case 5

This case discusses the results at Mill E, a Subcategory 5 Knit Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

During the pilot plant testing of the candidate mode treatment technologies at this mill, samples were collected to evaluate the effectiveness of the technologies in removing toxic pollutants. The reactor/clarifier was part of one mode of treatment, and testing was such that the unit could be evaluated independently. Data on the effectiveness are presented below.

Toxic Pollutant Treatability at Mill E
Influent and Effluent to Reactor/Clarifier

	Influent*			Effluent*		
Toxic Pollutant	Min	Max	n	Min	Max	n
Benzene	ND	15	10	ND	3	3
Chloroform	ND	210	10	9	73	3
Phenol	ND	T	10	ND	670	3
Bis(2-ethylhexyl) Phthalate	T	110	10	T	18	3
Antimony	22	600	8	10	43	3
Chromium	T	100	8	T	T	3
Copper	T	36	8	T	12	3
Cyanide	10#	10#	10	10#	10#	5
Lead	22#	34	8	22#	22#	3
Nickel	66	190	8	43	77	3
Silver	T	73	8	T	23	3
Zinc	155	5200	8	145	155	3

* concentrations in ug/l
T trace
\# reported as "less than" value
n number of samples
ND not detected

The following were detected at less than 10 ug/l in the influent and effluent: 1,2,4-Trichlorobenzene; 1,2-Dichlorobenzene; Ethylbenzene; Methylene Chloride; Naphthalene; N-nitrosodi-n-propylamine; Di-n-butyl Phthalate; Diethyl Phthalate; Anthracene; Toluene; Beryllium; Cadmium; Selenium.

Case 6

This case discusses the results at Mill A, a Subcategory 1 Wool Scouring mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

During the pilot plant testing of the candidate mode treatment technologies at this mill, samples were collected over a typical 24-hour period of operation to evaluate the effectiveness of the technologies in removing toxic pollutants. The reactor/clarifier was part of one mode of treatment, and testing was such that the unit could be evaluated independently. Data on the effectiveness are presented below.

Toxic Pollutant Treatability at Mill A
Influent and Effluent to Reactor/Clarifier

Toxic Pollutant	Influent, ug/l	Effluent, ug/l
Phenol*	16	17
Bis(2-ethylhexyl) Phthalate	42	23
Antimony	540	T
Arsenic	38	39
Cadmium	130	ND
Copper	320	110
Cyanide	200	240
Lead	3500	ND
Nickel	2000	ND
Silver	500	ND
Zinc	1500	190

* represents total of all toxic pollutant phenols
T trace
ND not detected

The following pollutants were detected at less than 10 ug/l in the influent and effluent: Ethylbenzene; Fluoranthene; Di-n-butyl Phthalate; Benzo(a)Anthracene; Benzo(a)Pyrene; Benzo(k)Fluoranthane; Anthracene; Toluene.

Case 7

This case discusses the results at Mill O, a Subcategory 2 Wool Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

During the pilot plant testing of the candidate mode treatment technologies at this mill, samples were collected over a typical 72-hour period of operation to evaluate the effectiveness of the technologies in treating toxic pollutants. One mode tested included the reactor/clarifier followed by multi-media filtration. Samples were collected around this mode and data on the effectiveness are presented below.

Toxic Pollutant Treatability at Mill O
Influent and Effluent to Reactor/Clarifier - Multi-Media Filter

Toxic Pollutant	Influent* Min	Influent* Max	Influent* n	Effluent* Min	Effluent* Max	Effluent* n
Methylene Chloride	46	46	3	28	28	1
Bis(2-Ethylhexyl) Phthalate	230	760	3	T	31	3
Chromium	158	206	3	30	47	3
Copper	4**	14	3	82	130	3
Lead	22**	22**	3	22**	22**	3
Nickel	36**	36**	3	36**	36**	3
Thallium	50**	50**	3	50**	50**	3
Zinc	639	1280	3	347	440	3

* concentrations in ug/l
** reported as "less than" value
T trace

The following pollutants were detected at less than 10 ug/l in the influent and effluent: Acrylonitrile; Benzene; 1,2,4-Trichlor0-benzene; 2,4,6-Trichlorophenol; Parachlorometacresol; Chloroform; 2-Chlorophenol; 1,2-Dichlorobenzene; Ethylbenzene; Fluoranthene; Naphthalene; N-nitrosodi-propylamine; Pentachlorophenol; Phenol; Di-n-butyl Phthalate; Diethyl Phthalate; Dimethyl Phthalate; Anthracene; Pyrene; Tetrachloroethylene; Toluene; Trichloroethylene; Antimony; Arsenic; Beryllium; Cadmium; Cyanide; Mercury; Selenium; Silver.

b. Precipitation

Precipitation is a chemical unit process in which undesirable soluble metallic ions are removed from water or wastewater by conversion to an insoluble form. It is a commonly used treatment technique for removal of hardness (calcium, magnesium, strontium, ferrous iron, and manganous ions and other metals), phosphorus, and the heavy metals. The procedure involves alteration of the ionic equilibrium to produce insoluble metallic hydroxides that can be easily settled in a clarifier. The hydroxide is usually supplied in the form of lime ($Ca(OH)_2$).

A typical precipitation reaction involving the removal of magnesium ions (Mg^{+2}) is:

$$Mg^{+2} + SO_4^{-2} + Ca(OH)_2 \quad Ca^{+2} + SO_4^{-2} + Mg(OH)_2$$

Metallic hydroxides have an optimal pH where they are most insoluble. For $Mg(OH)_2$, noted in the equation above, 10.8 is considered optimal. When precipitation of several metals is required, a pH of about 9 is often useful in practice.

Precipitation of chromium, a frequent constituent of some textile wastewaters, sometimes requires an additional step when chromium exists in the hexavalent state (Cr^{+6}) in wastewater it must be reduced to the trivalent state (Cr^{+3}) before precipitation can be achieved. The reducing agents commonly used are ferrous sulfate, sodium metabisulfate, and sulfur dioxide. If ferrous sulfate is used, acid must be added for pH adjustment.

Industry Application. Precipitation was not reported as a treatment method by any of the direct or indirect dischargers surveyed. It is suspected, however, that the distinction between coagulation and precipitation was not clearly established by at least some of those reporting coagulation as a part of their treatment system. It is probable that some of these mills may, in fact, be practicing precipitation for the removal of toxic metals. One reason for the limited application of precipitation may be that some of the auxiliary chemicals used in dyeing can act as complexing agents with heavy metals. These chemicals act as chelants and make the metals less susceptible to precipitation.

Literature/Research. Literature directly related to the treatment of textile wastewaters by employing precipitation is generally limited. The case presented below offers information on one investigation that is relevant.

Case 1

This case presents the findings of a research study (67) conducted to compare the effectiveness of chemical precipitation using lime and that using sulfide.

The sulfide removes heavy metal from solution in the form of sulfide precipitates and can be advantageous since metal sulfides are several orders of magnitude less soluble than the corresponding metal hydroxides. It is especially advantageous for the removal of hexavalent chrome because the process does not require a separate pretreatment step.

A wastewater sample from the aeration basin of a Subcategory 5b Knit Fabric Finishing mill was used in the comparison studies. The mill dyes 95 percent of the production and uses acid (64 percent), direct (32 percent), sulfur (2 percent), dispersed (1 percent), and reactive (1 percent) dyes. Data on the effectiveness of each precipitant are summarized below:

		Concentration, mg/l	
Metal	Raw Sample	Lime Effluent	Sulfide Effluent
Zinc	3.2	0.11	0.09
Nickel	0.05	-	-
Iron	2.3	0.17	0.19
Cadmium	0.01	-	-
Copper	0.50	0.03	0.01
Lead	0.10	-	-
Silver	0.05	-	-
Total Chromium	0.93	0.08	0.05

The data indicate that for the most part, somewhat greater metals reduction can be achieved with the sulfide precipitant.

c. Oxidation

Oxidation of wastewater is a chemical unit process that can be used to remove color, to remove ammonia, to reduce the concentration of organics, and to reduce the bacterial and viral content. It has been used for some time in the form of chlorine for the disinfection of effluents. Other available and tested oxidants include: hydrogen peroxide, potassium permanganate, chlorine dioxide, and ozone.

Chemical oxidation can provide the more powerful action often necessary to break down highly resistant industrial wastes. Potassium permanganate, chlorine, and ozone also have been used to reduce organic loads prior to biological treatment. In advanced wastewater treatment of industrial wastes, oxidation with ozone has shown the most promising application.

Ozone (O_3) is a faintly blue, pungent-smelling, unstable gas that exists as an allotropic form of oxygen. Because of its instability, ozone must be generated on-site. Ozone generators utilize a corona discharge that occurs when a high-voltage alternating current is imposed across a discharge gap. The method is highly inefficient in that only about 10 percent of the applied energy goes into ozone. Improvement in efficiency can be achieved if pure oxygen is used in the generator in lieu of air.

Ozone reacts rapidly with the majority of organic compounds and micro-organisms present in industrial wastewaters. It is capable of removing color in textile wastewaters but, because of the high dosages often required, is not suitable for reducing the concentration of organics.

Industry Application. Sixty of the direct dischargers and 11 of the indirect dischargers surveyed report using oxidation as part of their treatment systems. All but one of the direct dischargers simply chlorinate for disinfection purposes. The other mill reports adding chlorine in a rapid-mix contact tank for both disinfection and decoloring. Four of the indirect dischargers also simply chlorinate for disinfection purposes. Five add chlorine, usually in the form of hypochlorite, to control color. The other two mills recycle part of the discharge and are most likely adding chlorine for disinfection purposes. There are no data available from the survey that can be used to demonstrate the effectiveness of chlorine oxidation for decolorization.

Literature/Research. Because of the desire to effectively remove color, oxidation of textile wastewaters has received considerable attention by the engineering and research communities. Ozone has been the primary oxidant studied. The following cases present the findings of those studies most relevant here.

Case 1

This case discusses the results of a laboratory investigation conducted by Snyder and Porter (68) on the effect of pH on the ability of ozone to reduce organic content and color from the dye wastes from three textile mills. Ozone was produced from compressed air by a commercial electric discharge ozone generator and fed at a rate of 0.5 g/hr through an experimental apparatus containing 500-ml samples of the dye wastes. The studies were conducted at room temperature and usual contact time was one hour. To check the effect of pH on ozone reactivity, each dye waste was studied at near neutral, at acidic, and at basic pH values. Adjustments in pH were made with sulfuric acid and sodium hydroxide.

The results of the investigation indicate that there is no steadfast rule concerning the effects of pH on the efficiency of the ozonation process in reducing the organic content of textile dye waste. The greater removals occurred in the acid pH samples, but, according to the researchers, this is in contrast to the results obtained by other researchers, where greater removals occurred in high pH samples. The average removals of organic content, as measured by COD, for the three samples were 8, 41, and 55 percent. This indicates that a low concentration ozone stream (1 g/l) is not feasible for the removal of the majority of organics in textile dye waste. However, in each sample tested, excellent color removal was observed. The researchers attributed the effective decolorization to the susceptibility of the amine function in the dye molecules to ozone attack.

Case 2

The case discusses the results of a laboratory investigation conducted by the Georgia Department of Natural Resources (69) on ozone treatment and disinfection of tufted carpet dye wastewater. The investigations were performed on effluent samples from the City of Dalton municipal wastewater treatment plant. Approximately 90 percent of the plant's flow originates from textile mills that are engaged in dyeing and other carpet finishing operations. The waste from these mills contain significant levels of unexhausted color bodies and auxiliary dye chemicals, which result in a colored and moderately high organic content waste at the municipal plant. At the time of the investigations, the plant was treating approximately 40 mgd by the extended-aeration activated sludge process.

The studies investigated the effectiveness of various dosages of ozone by monitoring color, COD, organic carbon, suspended solids (SS), BOD_5, total and fecal coliform, anionic detergents, dissolved oxygen, and ozone residual before and after ozonation.

Grab samples were collected from the treatment plant effluent on five occasions between April 4 and June 21, 1973. Portions of the samples were placed in a 10-gallon capacity plexiglas contact column and ozonated gas was injected at a fixed feed rate. Samples were withdrawn from the column at specified time intervals for analysis. Results of the investigations are summarized for the parameters of most interest here in the following table.

Parameter	Ozone Dosage, mg/l	Parameter Concentration, mg/l Dalton Effluent	Ozonated Effluent
Color (filtered)	5	300*	125*
Color (filtered)	10	300*	95*
Color (filtered)	14	300*	60*
Color (filtered)	26	300*	32*
Color (filtered)	45	300*	18*
COD	3	130	125
COD	6	130	110
COD	20	130	100
COD	42	130	75
COD	60	130	75
SS	7	20	12
SS	19	20	8
SS	24	20	6
SS	52	20	2
BOD_5	8	21	27
BOD_5	14	21	53
BOD_5	19	21	25
BOD_5	25	21	20
BOD_5	33	21	19
Biphenyl	5	2.0	1.98
Biphenyl	12	2.0	1.35
Biphenyl	20	2.0	1.62
Biphenyl	26	2.0	1.19
Biphenyl	42	2.0	1.21
Biphenyl	89	2.0	0.10

* APHA Units

Conclusions regarding these parameters were stated as follows:

1. True color was reduced to less than 30 APHA Units at an ozone dosage of 40 mg/l; suspended solids reduction reduced the necessary ozone dosage to 26.5 mg/l.

2. COD reductions of 40 percent were achieved at ozone dosages of 45 mg/l; suspended solids removal did not significantly enhance COD reduction.

3. Suspended solids were reduced by approximately 90 percent with an ozone dosage of 52 mg/l.

4. The BOD_5 was essentially unchanged at all ozone dosages.

5. Biphenyls were reduced from approximately 2 mg/l to less than 0.1 mg/l at an ozone dosage of 89 mg/l.

EPA/Industry Field Studies. In a joint research effort between EPA and the textile industry (ATMI, NTA, and CRI), pilot plant studies were conducted during 1977 and 1978 at 19 textile mills to evaluate the effectiveness of alternative advanced wastewater treatment technologies. The studies were performed on the effluent from treatment systems employing the recommended BPT level of treatment. One of the alternatives was ozonation using a 110-liter (416-gal) contactor (Schedule 80 PVC column, 77 inches high and 11.6 inches inside diameter). Ozone was generated with a commercial ozone generator (PCI Ozone Corporation Model C2P-3C) with a capacity of 6 g/hr (pure oxygen feed) and fed through diffusers of 70 mesh stainless steel screen. The contactors could be operated in either a batch or a continuous mode. The offgases were sampled to determine concentration of ozone and thus permit calculation of ozone utilization. The available results of the ozonation studies are summarized in the following cases.

Case 1

This case discusses the results at Mill D, a Subcategory 4c Woven Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

Secondary clarifier effluent prior to chlorination was used in the pilot plant tests at Mill D. One candidate mode of operation tested included multi-media filtration, activated carbon, and ozonation. The operating characteristics and data on the effectiveness of ozonation during this mode are presented below.

Conventional and Non-Conventional Pollutant Treatability at Mill D
Influent and Effluent to Ozone Contactor*

	Influent			Effluent		
Pollutant	$\bar{x}$	SD	n	$\bar{x}$	SD	n
BOD_5, mg/l	13	7	21	47	12	18
COD, mg/l	422	142	22	349	115	17
TSS, mg/l	23	13	21	16	13	18
TOC, mg/l	101	40	14	106	31	13
Color, ADMI	825	239	14	149	149	14

* 427 mg/l ozone utilized (continuous operation)
$\bar{x}$ mean
SD standard deviation
n number of samples

Case 2

This case discusses the results at Mill Q, a Subcategory 5 Knit Fabric Finishing mill. This facility is actually two separate Knit Fabric Finishing mills that discharge to a common treatment plant. A description of the manufacturing operations and wastewater treatment at these mills is provided in Appendix F.

Secondary clarifier effluent prior to chlorination was used in the pilot plant tests at Mill Q. One candidate mode tested multi-media filtration and ozonation. The operating characteristics and data on the effectivness of ozonation during this mode are presented below.

Conventional and Non-Conventional Pollutant Treatability at Mill Q
Influent and Effluent to Ozone Contactor*

Pollutant	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	4.2	1	8	4.9	2.8	8
COD, mg/l	206	16	8	17	6.5	8
TSS, mg/l	4.5	3.3	8	3	1.4	2
TOC, mg/l	22	1.4	2	15	7.1	2
Color, ADMI	179	109	3	51	-	2

* 1130-1500 mg/l ozone utilized (batch operation)
$\bar{x}$ mean
SD standard deviation
n number of samples

In addition to the regular pilot plant studies at this facility, samples were collected on two consecutive days to evaluate the effectiveness of the pilot plant technologies in the treatment of toxic pollutants. One mode tested was multi-media filtration followed by ozonation. Samples were collected before filtration and after ozonation. The filter was operated at a surface loading rate of 3 gpm/ft^2 and an ozone dosage (utilized) between 1130 to 1500 mg/l was applied. Data on the effectiveness of this mode of treatment are presented below.

Toxic Pollutant Treatability at Mill Q
Influent and Effluent to Multi-Media Filter - Ozone Contactor Mode

Toxic Pollutant	Influent* Min	Influent* Max	Influent* n	Effluent* Min	Effluent* Max	Effluent* n
Bis(2-ethylhexyl) Phthalate		15	1#		45	1#
Tetrachloroethylene		17	1#		ND	1#
Antimony	622	684	2		687	1#
Cadmium	ND	ND	2		17	1#
Copper	102	106	2		88	1#
Cyanide	ND	ND	2		20	1#
Lead		48	1#		53	1#
Nickel	ND	ND	2		44	1#
Selenium	20	62	2		ND	1#
Silver		13	1#		19	1#
Zinc	47	50	2		180	1#

* Concentrations in ug/l
\# Composite sample, Day 1 and Day 2
ND not detected
n number of samples

The following pollutants were detected at less than 10 ug/l in the influent and effluent: 2-Nitrophenol; Arsenic.

Case 3

This case discusses the results at Mill A, a Subcategory 1 Wool Scouring facility. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

During the pilot plant testing of the candidate mode treatment technologies at this mill, samples were collected over a typical 24-hour period of operation to evaluate the effectiveness of the technologies in removing toxic pollutants. The ozone contactor was part of one mode of treatment, and testing was such that the unit could be evaluated independently. Data on the effectiveness are presented below.

Toxic Pollutant Treatability at Mill A
Influent and Effluent to Ozone Contactor

Toxic Pollutant	Influent, ug/l	Effluent, ug/l
Phenol*	17	13
Bis(2-ethylhexyl) Phthalate	14	106
Antimony	T	1200
Arsenic	83	43
Cadmium	ND	250
Copper	120	590
Cyanide	260	ND
Lead	ND	ND
Nickel	ND	ND
Silver	ND	1300
Zinc	400	460

* represents total of all toxic pollutant phenols
T trace
ND not detected

The following pollutants were detected at less than 10 ug/l in the influent and effluent: Ethylbenzene; Fluoranthene; Di-n-butyl Phthalate; Benzo(a)Anthracene; Benzo(a)Pyrene; Benzo(k)Fluoranthene; Anthracene; Toluene.

4. Physical Separation

a. Filtration

Wastewater filtration is a physical unit operation that is used to remove suspended materials. It may be employed to polish an existing biological effluent to prepare wastewater for subsequent advanced treatment processes, or to enable direct reuse of a discharge. Primary applications that are discussed in this section include: 1) direct filtration of secondary biological effluents alone or as pretreatment for carbon or ozone, 2) filtration of chemically clarified effluent, and 3) filtration of secondary biological effluents following in-line chemical injection (precoagulation).

The filtration process separates suspended material from wastewater by passing the waste through porous material. The mechanisms responsible for removal include: straining, sedimentation, inertial impaction, interception, adhesion, chemical adsorption (bonding and chemical interaction), physical adsorption (electrostatic, electrokinetic, and Van der Waals forces), and two accessory actions within the filter bed-biological growth and flocculation. The mechanisms that will predominate depend on the wastewater characteristics and the characteristics of the filter (media composition; grain size, shape, density, and porosity; bed depth; and filtration rate). (64, 70)

Filtration systems are broadly classified as either "surface" or "in-depth." Surface filters include microscreens, diatomaceous earth filters, and moving bed filters. These filters achieve solids removal primarily by surface straining and, as a result, yield shorter-length runs between backwashings. In-depth filters include deep-bed single-, dual-, or multi-media units. Graded sand was commonly used in the past for in-depth filtration but today, garnet, gravel, resin beads, activated carbon, and anthracite coal are also commonly used. The use of multiple layers of different media having specific gravities increasing in the direction of flow permits gradation of the filter bed and allows more efficient utilization of the total bed depth.

Industry Application. Sixteen mills report using filtration as part of their treatment systems. Ten are direct dischargers, 3 are indirect dischargers, and 3 practice complete recycle. All but one of the direct dischargers employ activated sludge or a similar biological process prior to filtration. Three of these dischargers also perform chemical coagulation or add coagulants in-line prior to filtration (precoagulation). Most of the direct dischargers report that their filters are of the multi-media type with sand, gravel, and anthracite media. They are operated as tertiary filters and are pressurized.

The filter systems employed by the indirect dischargers include an in-depth sand filter, a vermiculite filter used to separate the floc from a chemically treated (coagulation and flocculation) waste, and a system that includes a multi-media (sand and charcoal) filter following biological aeration. Two plants practicing recycle are operated by the same company and both employ multi-media in-depth filters using gravel, sand, and anthracite media. In both cases the filtration systems follow extended-aeration activated sludge and chemical coagulation. The third recycle plant precedes filtration with air flotation, biological aeration, and chemical coagulation/flocculation.

Although many of the filtration systems are operated to polish biological and/or chemically treated effluents or to allow recycle, the available data from these mills, i.e., influent and effluent for the entire treatment system, do not presently demonstrate the effectiveness of the filtration systems alone. The following tabulation does demonstrate the overall effectiveness of the treatment systems that include filtration. The data represent average values for those mills that provided historical monitoring results and generally represent sampling during 1976.

Subcategory	Filter Type	Treatment Step	BOD, mg/l Inf	BOD, mg/l Eff	COD, mg/l Inf	COD, mg/l Eff	TSS, mg/l Inf	TSS, mg/l Eff
		(Direct Discharge)						
5a	Multi-media In-depth	Polishing	-	159	-	-	-	65
5a	Dual-media In-depth	Polishing	-	33	-	188	-	55
5a	-	Polishing	334	24	1265	206	-	40
5a	Sand In-depth	Polishing	327	43	1261	427	119	88
5a	Multi-media Pressure	Polishing	279	5	934	196	41	7
7	Sand In-depth	Post Flotation	-	17	-	-	-	21
7	Multi-media Pressure	Polishing	327	20	1572	480	26	23
7	Dual-media In-depth	Polishing	218	23	800	312	12	93
		(Recycle)						
4a	Dual-media Pressure	Polishing	298	10	-	1550	-	5

Literature/Research. Although considerable attention has been given to filtration of textile wastewaters, very little historical or research data exist that demonstrate the effectiveness of filtration systems. While there are a number of filters in place to polish the effluent from biological and biological/chemical treatment systems (see Industry Application), none are routinely monitored for conventional pollutants and no data exist on their effectiveness in treating priority pollutants. Sampling was conducted at four mills during this study to provide such information. The results are summarized in the following cases.

Case 1

This case discusses the results at two Subcategory 5b Knit Fabric Finishing mills that discharge to a common treatment plant. This facility was part of the EPA/Industry pilot plant field studies (Mill

Q); a description of the manufacturing operations and wastewater treatment is provided in Appendix F.

Samples were collected over a 48-hour period at the influent to the treatment plant, following secondary clarification, and at the effluent. The results presented below demonstrate the effectiveness of the biological system and the multi-media pressure filter in treating conventional, non-conventional, and toxic pollutants.

Conventional and Non-Conventional Pollutant Treatability

Pollutant Parameter	Raw Waste*	Secondary Effluent**	Final Effluent**
BOD_5, mg/l	-	-	-
COD, mg/l	782	312	233
TSS, mg/l	17	28	6
Oil & Grease, mg/l	324	303	476
Color, ADMI	288	187	192
Phenols, ug/l	-	59	48
Sulfide, ug/l	ND	ND	ND

* 48-hour composite sample
** average of two 24-hour composite samples
ND not detected

Toxic Pollutant Treatability

Toxic Pollutant	Raw Waste*	Concentration, ug/l Secondary Effluent**	Final Effluent**
1,2,4-Trichlorobenzene	2700	ND	ND
Ethylbenzene	101	ND	ND
Naphtalene	45	ND	ND
Phenol	55	ND	ND
Bis(2-ethylhexyl) Phthalate	41	15	12
Tetrachloroethylene	ND	17	17
Trichloroethylene	840	ND	ND
Antimony	95	670*	700*
Chromium	14	32*	32*
Copper	44	104*	79*
Cyanide	10	ND	10*
Lead	36	48*	33*
Nickel	36	ND	ND
Selenium	15	41*	102*
Silver	12	13*	8*
Zinc	56	48*	84*

* average of two 24-hour grab samples
ND not detected

The following pollutants were detected at less than 10 ug/l in the raw waste, secondary effluent, and/or final effluent: 2,4,6-Trichlorophenol; 2-Nitrophenol.

Case 2

This case discusses the results at a Subcategory 4a Woven Fabric Finishing mill that performs flat bed and rotary screen printing to produce sheets, towels, and bedspreads. Rotary screening printing accounts for approximately 90 percent of the production, which was reported as 30,000 kg/day (approximately 65,000 lb/day). The processing operations result in a water usage of 19.2 l/kg (2.3 gal/lb) and a wastewater discharge of 570 cu m/day (150,000 gpd).

Wastewater treatment at this mill consists of equalization (small holding tank), grit removal, coarse screening, chemical addition (alum and caustic), fine screening, (SWECO vibrating screens), chemical addition (cationic polymer) and flocculation, dissolved air flotation (300 gpm), biological aeration (2 lagoons in series with a total volume of 1.64 mil gal), disinfection (chlorine), secondary clarification (reactor/clarifier in which alum, caustic, and anionic polymer are added), and dual-media gravity filtration (sand and carbon). Aeration detention time is approximately 170 hours, and air is provided by surface aerators at a power-to-volume ratio of approximately 18 hp/mil gal. The discharge from the treatment plant is recycled for reuse in the printing operations.

Samples were collected (see Appendix D for sampling procedures) over a typical 48-hour period of operation at the bar screen prior to the air flotation unit, at the Parshall flume prior to the aeration basins, at the chlorine contact chamber following aeration, and at the effluent from the dual-media filter. The results presented below demonstrate the effectiveness of the reactor/clarifier - dual-media filter in treating conventional, non-conventional, and toxic pollutants.

Conventional and Non-Conventional Pollutant Treatability*

Pollutant Parameter	Biological Influent	Biological Effluent	Filter Effluent
BOD_5, mg/l	200**	67**	20**
COD, mg/l	725	577	543
TSS, mg/l	32	17	4
Phenols, ug/l	26	18	14
Sulfide, ug/l	200**	200**	200**

* average of two 24-hour samples
** reported as "less than" value

Toxic Pollutant Treatablity

Toxic Pollutant	Concentration, ug/l Biological Influent	Biological Effluent	Filter Effluent
Benzene	19	5*	5*
Ethylbenzene	160	ND	ND
Methyl Chloride	56	5*	5*
4-Nitrophenol	13	10*	10*
Pentachlorophenol	34	ND	ND
Phenol	32	24	16
Bis(2-ethylhexyl) Phthalate	45	ND	ND
Toluene	200	ND	ND
Copper	81**	52**	27**
Lead	NS	32**	NS
Nickel	32**	32**	NS
Thallium	14**	13**	NS

* reported as "less than" value
** average of two 24-hour grab samples
ND not detected
NS no sample

The following pollutants were detected at less than 10 ug/l in the biological influent biological effluent, and final effluent: 1,2-Dichloroethane; 1,1,1-Trichloroethane; Tetrachloroethylene; Trichloroethylene; Beryllium; Cadmium; Chromium; Cyanide; Mercury; Silver; Zinc.

Case 3

This case discusses the results at a Subcategory 7 Stock & Yarn Finishing facility that performs package dyeing of polyester, cotton, and wool yarn. Dispersed dye is the primary dye class employed, although some acid and cationic dyes also are used. Average production is reported as 22,680 kg/day (50,000 lb/day). The processing results in an average water usage of 154 l/kg (18.5 gal/lb) and a wastewater discharge of 3,500 cu m/day (925,000 gpd).

Wastewater treatment at this mill consists of coarse screening, neutralization, biological aeration (one basin with a total volume of 5,250,000 gal), secondary clarification, dual-media gravity filtration (sand and carbon), and disinfection (chlorine). Aeration detention time is approximately 120 hours, and air is provided by eight surface aerators with a total power-to-volume ratio of approximately 114 hp/mil gal. The carbon in the filter has not been changed within the past two years and may not be functioning in an adsorptive capacity.

Samples were collected (see Appendix D for sampling procedures) over a 72-hour period of operation of the raw wastewater, the secondary clarifier effluent, and the filter effluent. The results presented below demonstrate the effectiveness of the activated sludge system and the dual-media filter in treating conventional, non-conventional, and toxic pollutants.

Conventional and Non-Conventional Pollutant Treatability

Pollutant Parameter	Biological Influent	Clarifier Effuent Min	Clarifier Effuent Max	n	Filter Effluent Min	Filter Effluent Max	n
COD, mg/l	226	116	150	3	122	148	3
TSS, mg/l	25	100	170	3	38	115	3
Phenols, ug/l	810	12	21	3	17	19	3
Sulfide, ug/l	44	6	8	3	9	9	3
Color, ADMI	131	112	124	3	105	113	3

Toxic Pollutant Treatability

Toxic Pollutant	Biological Influent	Clarifier Effuent Min	Clarifier Effuent Max	n	Filter Effluent Min	Filter Effluent Max	n
Acrylonitrile	ND	ND	100**	3	ND	100**	3
1,2,4-Trichlorobenzene	270	19	43	3	T	21	3
Bis(chloromethyl) Ether	59	ND	ND	3	ND	ND	3
2,4,6-Trichlorophenol	16	T	T	3	ND	T	3
Parachlorometa Cresol	29	ND	T	3	ND	T	3
1,2-Dichlorobenzene	56*	ND	T	3	T	T	3
2,4-Dichlorophenol	20	ND	ND	3	ND	ND	3
1,2-Dichloropropane	56	ND	ND	3	ND	ND	3
2,4-Dimethylphenol	190	ND	ND	3	ND	ND	3
Naphthalene	18	ND	13	3	T	T	3
Pentachlorophenol	ND	ND	23	3	ND	13	3
Bis(2-ethylhexyl) Phthalate	490	76	340	3	80	170	3
Di-n-butyl Phthalate	24	ND	T	3	ND	T	3
Dimethyl Phthalate	18	ND	ND	3	ND	ND	3
Tetrachloroethylene	310	T	T	3	T	9	3
Toluene	T	T	38	3	T	T	3
Trichloroethylene	10	ND	ND	3	ND	ND	3
Antimony	156	141	177	3	150	162	3
Arsenic	19	T	T	3	T	T	3
Chromium	34	68	91	3	12	57	3
Copper	49	110	132	3	20	84	3
Lead	22**	22**	35	3	22**	22**	3
Nickel	36**	36**	36**	3	42	50	3
Silver	T	T	T	3	11	15	3
Thallium	50**	ND	50**	3	ND	50**	3
Zinc	493	228	283	3	139	436	3

* represent sum of concentrations of 1,2-Dichlorobenzene; 1,3-Dichlorobene; and 1,4-Dichlorobenzene

** reported as "less than" value

ND not detected

The following pollutants were detected at less than 10 ug/l in the biological influent, clarifier effluent, or filter effluent: Benzene; Hexachlorobenzene; Chloroform; Ethylbenzene; Fluoranthane; Methylene Chloride; N-nitrosodi-n-propylamine; Phenol; Butyl Benzyl Phthalate; Diethyl Phthlate; Anthracene; Fluorene; Pyrene; Beryllium; Cadmium; Cyanide; Mercury; Selenium.

EPA/Industry Field Studies. In a joint research effort between EPA and the textile industry (ATMI, NTA, and CRI), pilot plant studies were conducted during 1977 and 1978 at 19 textile mills to evaluate the effectiveness of alternative advanced wastewater treatment technologies. The studies were performed on the effluent from treatment systems employing the recommended BPT level of treatment. One of the alternatives was downflow multi-media filtration using one of two filters 63 inches in height and 14 inches in diameter. Each filter provided one foot of surface area and contained 12 inches of anthracite coal (0.9 - 1.5 mm effective size), 12 inches of sand (0.4 - 0.8 mm effective size), and 16 inches of gravel (6 - 16 mm effective size). The available results of the filtration studies are summarized in the following cases.

Case 1

This case discusses the results at Mill D, a Subcategory 4c Woven Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

Secondary clarifier effluent prior to chlorination was used in the pilot plant tests at this mill. Two candidate modes were tested and both included multi-media filtration. One mode consisted of multi-media filtration followed by activated carbon; the other mode additionally included ozonation. The operating characteristics and data on the effectiveness of multi-media filtration are presented below.

Conventional and Non-Conventional Pollutant Treatability at Mill D
Influent and Effluent to Multi-Media Filter*

Pollutant	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	24	14	17	19	9	15
COD, mg/l	814	284	19	630	177	19
TSS, mg/l	294	422	17	85	100	16
TOC, mg/l	179	65	14	157	64	32
Color, ADMI	1007	696	12	1070	-	2

* filter operated at an average surface loading rate of 4.4 gpm/ft^2
$\bar{x}$ mean
SD standard deviation
n number of samples

Case 2

This case discusses the results at Mill DD, a two-facility complex that performs woven fabric and stock & yarn finishing. A Low Water Use Processing operation (griege mill) also is associated with this complex. A description of the manufacturing operations and wastewater treatment at this facility is provided in Appendix F.

Multi-media filtration was part of both candidate modes at Mill DD. However, the effectiveness of multi-media filtration alone cannot be evaluated based on the available data.

In addition to the regular pilot plant studies at this facility, samples were collected over a typical 8-hour operating period to evaluate the effectiveness of the pilot plant technologies in treating priority pollutants. One mode of operation tested was multi-media filtration with alum added as a precoagulant. The surface loading rate to the filter ranged from 1 to 4 gpm/ft^2 and the alum dosage was 20 mg/l as Al^{+3}. Data on the effectiveness are presented below.

Toxic Pollutant Treatability at Mill DD
Influent and Effluent to Multi-Media Filter

Toxic Pollutant	Influent, ug/l	Effluent, ug/l
Chromium	58	110
Copper	59	28
Lead	37	31
Nickel	72	67
Silver	25	28
Zinc	190	280

The following pollutants were detected at less than 10 ug/l in the influent and effluent to the filter: Bis(2-ethylhexyl) Phthalate; Diethyl Phthalate; Dimethyl Phthalate; Arsenic; Cadmium.

Case 3

This case discusses the results at Mill B, a Subcategory 2 Wool Finishing mill. A description of the manufacturing operation and wastewater treatment at this mill is provided in Appendix F.

Secondary clarifier effluent prior to chlorination was used in the pilot plant tests at Mill B. Two candidate modes utilized multi-media filtration. One mode included the reactor/clarifier before filtration with carbon adsorption afterwards. The other mode included the reactor/ clarifier multi-media filtration, and ozonation. The operating characteristics and data on the effectiveness of multi-media filtration during each mode are presented below.

Conventional and Non-Conventional Pollutant Treatability at Mill B
Influent and Effluent to Multi-Media Filter*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD5, mg/l	39	13	9	31	1.4	9
COD, mg/l	194	68	9	174	72	9
TSS, mg/l	6	6	9	2	3	9
TOC, mg/l	68	29	9	65	29	9

* Filter operated at an average surface loading rate of 7.0 gpm/ft^2 (9/6 - 9/13/77).
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill B
Influent and Effluent to Multi-Media Filter*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD5, mg/l	17	-	1	23	-	1
COD, mg/l	216	137	3	157	124	3
TSS, mg/l	82	86	3	31	29	3
TOC, mg/l	77	45	3	69	38	3

* Filter operated at an average surface loading rate of 6.6 gpm/ft^2 (9/11 - 9/12/77).
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill B
Influent and Effluent to Multi-Media Filter*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	27	14	9	20	10	9
COD, mg/l	229	5	9	203	54	9
TSS, mg/l	33	36	9	15	23	9
TOC, mg/l	76	28	6	41	16	4

* Filter operated at an average surface loading rate of 5.4 gpm/ft² (9/13 - 9/21/77).

$\bar{x}$ mean
SD standard deviation
n number of samples

In addition to the regular pilot plant studies at this facility, samples were collected over a 24-hr period to evaluate the effectiveness of the candidate modes in treating toxic pollutants. The candidate mode tested included the reactor/clarifier followed by multi-media filtration followed by carbon adsorption. The reactor/clarifier was loaded at a rate of 400 gpd/ft² with 35 mg/l alum as (Al^{+3}) added as a coagulant, the multi-media filter was loaded at a rate of 5.4 gpm/ft², and the carbon columns were operated at an empty bed retention time of 25 to 30 minutes. Data on the effectiveness of the multi-media filter are presented below.

Toxic Pollutant Treatability at Mill B
Influent and Effluent to Multi-Media Filter

Toxic Pollutant	Influent, ug/l	Effluent ug/l
1,2,4-Trichlorobenzene	154	94
Pentachlorophenol	ND	10
Bis(2-ethylhexyl) Phthalate	44	14
Toluene	14	12
Antimony	23	12
Arsenic	62	103
Cadmium	T	105
Chromium	41	41
Copper	16	118
Lead	30	116
Nickel	57	73
Silver	172	158
Zinc	5730	5800

T trace
ND not detected

The following pollutants were detected at less than 10 ug/l in the influent and effluent: 1,2-Dichlorobenzene; 2,4-Dimethylphenol, N-nitrosodiphenylamine; Benzo(a)Pryrene.

Case 4

This case discusses the results at Mill P, a Subcategory 4c Woven Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

Two candidate modes utilized multi-media filtration as the first treatment operation at Mill P. One mode included filtration with precoagulation and the other followed this treatment with activated carbon adsorption. Testing was performed on the secondary clarifier effluent prior to chlorination. The operating characteristics and data on the effectiveness of multi-media filtration during the testing are presented below.

Conventional and Non-Conventional Pollutant Treatability at Mill P
Influent and Effluent to Multi-Media Filter*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	11	9	5	9	6	4
COD, mg/l	122	54	5	98	15	5
TSS, mg/l	10	4	5	21	15	5
TOC, mg/l	20	7	5	23	4	5
Color, ADMI	138	21	3	141	28	3

* surface loading of 3 gpm/ft^2 and a precoagulant alum dose of 1.5 mg/l (as Al^{+3}).
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill P
Influent and Effluent to Multi-Media Filter*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	3	-	-	38	-	-
COD, mg/l	122	-	-	130	-	-
TSS, mg/l	25	-	-	10	-	-
TOC, mg/l	29	-	-	25	-	-
Color, ADMI	163	-	-	162	-	-

* surface loading of 3 gpm/ft^2 and a precoagulant alum dose of 1.5 mg/l (as Al^{+3}).
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill P
Influent and Effluent to Multi-Media Filter*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	11	-	2	11	-	2
COD, mg/l	85	-	2	118	-	2
TSS, mg/l	153	-	2	17	-	2
TOC, mg/l	36	-	2	27	-	2
Color, ADMI	154	-	-	161	-	-

* surface loading rate of 5 gpm/ft^2 and a precoagulant alum dose of 1.5 mg/l (as Al^{+3}).
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill P
Influent and Effluent to Multi-Media Filter*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	26	-	-	8	-	-
COD, mg/l	109	-	-	83	-	-
TSS, mg/l	11	-	-	12	-	-
TOC, mg/l	29	-	-	27	-	-
Color, ADMI	149	-	-	150	-	-

* surface loading rate of 5 gpm/ft^2 and a precoagulant alum dose of 2.7 mg/l (as Al^{+3}).
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill P
Influent and Effluent to Multi-Media Filter*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	11	-	2	10	-	2
COD, mg/l	85	-	2	113	-	2
TSS, mg/l	153	-	2	20	-	2
TOC, mg/l	36	-	2	25	-	2
Color, ADMI	154	-	-	160	-	-

* surface loading rate of 7 gpm/ft^2 and a precoagulant alum dose of 1.5 mg/l (as Al^{+3}).

$\bar{x}$ mean

SD standard deviation

n number of samples

Case 5

This case discusses the results at Mill Q, a Subcategory 5b Knit Fabric Finishing mill. This facility is actually two separate Knit Fabric Finishing mills that discharge to a common treatment plant. A description of the manufacturing operations and wastewater treatment at these mills is provided in Appendix F.

Multi-media filtration was used as part of the treatment in three candidate modes tested at Mill Q. One mode consisted of the reactor/clarifier followed by multi-media filtration, another consisted of multi-media filtration followed by activated carbon, and the last consisted of multi-media filtration followed by ozonation. Testing was performed on the secondary clarifier effluent prior to chlorination, with and without a precoagulant added. The operating characteristics and data on the effectiveness of multi-media filtration during the testing are presented below.

Conventional and Non-Conventional Pollutant Treatability at Mill Q
Influent and Effluent to Multi-Media Filter*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	10	4.3	4	7	1.3	4
COD, mg/l	338	36	4	258	26	4
TSS, mg/l	77	24	4	28	19	4
TOC, mg/l	18	0.6	3	18	0.6	3
Color, ADMI	-	-	-	-	-	-

* surface loading rate of 2.5 gpm/ft^2 and a precoagulant alum dose of 1 mg/l (as Al^{+3}).
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill Q
Influent and Effluent to Multi-Media Filter*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	8.5	1.4	6	4	0.7	6
COD, mg/l	273	15	6	202	10	6
TSS, mg/l	48	6.8	6	4.5	2.6	6
TOC, mg/l	-	-	-	-	-	-
Color, ADMI	214	68	6	205	45	5

* surface loading rate of 2.0 gpm/ft^2.
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill Q
Influent and Effluent to Multi-Media Filter*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	8	2	14	4	1	14
COD, mg/l	272	32	14	208	17	14
TSS, mg/l	45	11	14	4	1.5	14
TOC, mg/l	27	3.8	3	22	1.7	3
Color, ADMI	252	24	7	250	14	6

* surface loading rate of 2.0 gpm/ft^2.
$\bar{x}$ mean
SD standard deviation
n number of samples

Case 6

This case discusses the results at Mill V, a Subcategory 4c Woven Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

The candidate mode selected for Mill V consisted of the reactor/clarifier followed by multi-media filtration followed by activated carbon adsorption. Testing was performed on secondary clarifier effluent prior to chlorination. The operating characteristics and data on the effectiveness of multi-media filtration during the testing are presented below.

Conventional and NonConventional Pollutant Treatability at Mill V
Influent and Effluent to Multi-Media Filter*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	3.6	2	14	2.5	1.2	14
COD, mg/l	352	35	14	331	31	14
TSS, mg/l	51	17	14	20	8	14
TOC, mg/l	72	9	14	62	8	14
Color, ADMI	274	57	13	283	49	11

* surface loading rate of 3.0 gpm/ft².
$\bar{x}$ mean
SD standard deviation
n number of samples

In addition to the regular pilot plant studies at this facility, samples were collected over a 24-hour period to evaluate the effectiveness of the candidate mode in removing toxic pollutants. The mode included the reactor/clarifier, multi-media filters, and activated carbon columns. The reactor/clarifier was operated at a surface loading rate of 400 gpd/ft^2 with a coagulant dosage of 40 mg/l alum (as Al^{+3}). The multi-media filters were loaded at a rate of 3.0 gpm/ft^2, and the carbon columns were operated at 0.46 gpm (empty bed retention time of 45 minutes). Data on the effectiveness of the multi-media filter are presented below.

Toxic Pollutant Treatability at Mill V
Influent and Effluent to Multi-Media Filter

Toxic Pollutant	Influent, ug/l	Effluent ug/l
1,2-Dichlorobenzene	13	trace
Pentachlorophenol	not detected	12
Bis(2-ethylhexyl) Phthalate	34	trace
Antimony	123	136
Chromium	17	14
Copper	11	25
Lead	66	64
Silver	72	77
Zinc	195	234

The following pollutants were detected at less than 10 ug/l in the influent and effluent: Ethylbenzene, Di-n-butyl Phthalate, Anthracene, Toluene, Arsenic, Cadmium, Nickel.

Case 7

This case discusses the results at Mill W, a Subcategory 5b Knit Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

Multi-media filtration was part of the treatment in both candidate modes selected for Mill W. One mode consisted of multi-media filtration followed by activated carbon adsorption. The second mode tested multi-media filtration with precoagulation. Testing was performed on secondary clarifier effluent prior to chlorination. The operating characteristics and data on the effectiveness of multi-media filtration during the testing are presented below.

Conventional and Non-Conventional Pollutant Treatability at Mill W
Influent and Effluent to Multi-Media Filter*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD5, mg/l	4.6	1.6	17	3.4	1.2	17
COD, mg/l	73	9	17	55	7	17
TSS, mg/l	26	9	17	9.5	4.7	17
TOC, mg/l	14	4.5	16	11	3.3	16
Color, ADMI	140	57	16	118	42	16

* surface loading rate of 7 gpm/ft^2.
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill W
Influent and Effluent to Multi-Media Filter*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	4.6	1.6	17	2.4	1.2	17
COD, mg/l	73	9	17	48	7	17
TSS, mg/l	26	9	17	13	6	17
TOC, mg/l	14	4.5	16	10	4	16
Color, ADMI	140	57	16	83	30	15

* surface loading rate of 5 gpm/ft^2 with a precoagulant dosage of 3 mg/l of 572C polymer.
$\bar{x}$ mean
SD standard deviation
n number of samples

In addition to the regular pilot plant studies at Mill W, daily samples were collected during the operation of each candidate mode to evaluate the effectiveness of the modes in treating toxic pollutants. The operating characteristics of the multi-media filtration/activated carbon mode were a 7 gpm/ft^2 loading rate through the filters and an empty bed retention time of 45 minutes for the carbon columns. The operating characteristics of the multi-media filtration with precoagulation mode were a 5 gpm/ft^2 loading rate and addition of 3 mg/l of anionic polymer. Data on the effectiveness of the multi-media filter are presented below.

Toxic Pollutant Treatability at Mill W
Influent and Effluent to Multi-Media Filter*

Toxic Pollutant	Influent** Min	Max	n	Effluent** Min	Max	n
Benzene	ND	10	7	ND	4	7
1,2,4-Trichlorobenzene	ND	29	6	ND	9	7
Chloroform	ND	1020	7	ND	790	7
Bis(2-ethylhexyl) Phthalate	ND	34	7	ND	44	7
Antimony	560	888	7	554	869	7
Arsenic	10#	10#	1	11	11	1
Copper	18	323	7	10	41	7
Lead	9	82	7	10	85	7
Nickel	36#	108	7	36#	114	7
Silver	5#	30	7	5#	32#	7
Thallium	50#	50#	1	50#	50#	1
Zinc	34	90	7	40	86	7

* multi-media filtration/activated carbon mode
** concentrations in ug/l

ND not detected
\# reported as "less than" valve
n number of samples

The following pollutants were detected at less than 10 ug/l in the influent and effluent: Acenaphthene; Parachlorometacresol; 2,4-Dichlorophenol; 2,4-Dimethylphenol; Ethylbenzene; Naphthalene; Phenol; Di-n-butyl Phthalate; Toluene; Trichloroethylene; Beryllium; Cadmium; Chromium; Cyanide, Mercury; Selenium.

Toxic Pollutant Treatability at Mill W
Influent and Effluent to Multi-Media Filter*

Toxic Pollutant	Influent** Min	Max	n	Effluent** Min	Max	n
Benzene	ND	10	7	ND	3	7
1,2,4-Trichlorobenzene	ND	29	6	ND	6	7
Chloroform	ND	1020	7	ND	7	7
Bis(2-ethylhexyl) Phthalate	ND	34	7	11	42	7
Antimony	560	867	7	479	888	7
Copper	18	323	7	9	27	7
Lead	9	82	7	28	81	7
Nickel	36#	108	7	34	137	7
Silver	5#	30	7	5#	41	7
Thallium	50#	50#	1	50#	50#	1
Zinc	34	90	7	48	93	7

* multi-media filtration with precoagulation mode.
** concentrations in ug/l
n number of samples
ND not detected
reported as "less than" value

The following pollutants were detected at less than 10 ug/l in the influent and effluent: Acenaphthene; Ethylbenzene; Naphthalene; Phenol; Di-n-butyl Phthalate; Toluene; Trichloroethylene; Arsenic, Beryllium; Cadmium; Chromium; Cyanide; Mercury; Selenium.

Case 8

This case discusses the results at Mill E, a Subcategory 5a Knit Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

During the pilot plant testing of the candidate mode treatment technologies at this mill, samples were collected to evaluate the effectiveness of the technologies in treating toxic pollutants. Multi-media filtration was part of two modes of treatment, and testing was such that the units could be evaluated independently. Data on the effectiveness of multi-media filtration are presented below.

Priority Pollutant Treatability at Mill E
Influent and Effluent to Multi-Media Filter*

Toxic Pollutant	Influent** Min	Max	n	Effluent** Min	Max	n
Benzene	ND	15	10	ND	T	10
Chloroform	ND	207	10	ND	10	10
N-nitrosodi-n-propylamine	ND	T	10	ND	26	10
Phenol	ND	T	10	ND	2110	10
Bis(2-ethylhexyl) Phthalate	T	109	10	T	20	10
Antimony	22#	600	8	10#	37	8
Chromium	T	98	8	T	12	8
Copper	T	36	8	T	26	8
Cyanide	10#	10#	10	10#	10#	10
Lead	22#	34	8	22#	27	8
Nickel	66	187	8	36	188	8
Silver	T	73	8	T	68	8
Zinc	155	5160	8	155	204	8

* Multi-Media Filter - Activated Carbon mode
** concentrations in ug/l
T trace
\# reported as "less than" value
n number of samples
ND not detected

The following were detected at less than 10 ug/l in the influent and effluent: 1,2,4-Trichlorobenzene; 1,2-Dichlorobenzene; Ethylbenzene; Methylene Chloride; Naphthalene; N-nitrosodi-n-propylamine; Di-n-butyl Phthalate; Diethyl Phthalate; Anthracene; Toluene; Beryllium; Cadmium; Selenium.

Toxic Pollutant Treatability at Mill E
Influent and Effluent to Multi-Media Filter*

Toxic Pollutant	Influent** Min	Max	n	Effluent** Min	Max	n
Benzene	ND	T	3	ND	144	10
Chloroform	T	73	3	ND	ND	10
Phenol	ND	669	3	ND	T	9
Bis(2-ethylhexyl) Phthalate	T	18	3	T	200	10
Antimony	10#	43	3	10#	48	8
Copper	4#	12	3	4#	20	8
Cyanide	10#	10#	5	10#	10#	10
Lead	22#	22#	3	22#	27	8
Nickel	43	77	3	36#	135	8
Silver	5#	23	3	5#	59	8
Zinc	145	155	3	144	160	8

* Reactor/Clarifier - Multi-Media Filter mode
** concentrations in ug/l
T trace
\# reported as "less than" value
n number of samples
ND not detected

Case 9

This case discusses the results at Mill A, a Subcategory 1 Wool Scouring facility. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

During the pilot plant testing of the candidate mode treatment technologies at this mill, samples were collected over a typical 24-hour period of operation to evaluate the effectiveness of the technologies in treating toxic pollutants. Multi-media filtration was part of one mode of treatment, and testing was such that the unit could be evaluated independently. Data on the effectiveness are presented below.

Toxic Pollutant Treatability at Mill A
Influent and Effluent Multi-Media Filter

Toxic Pollutant	Influent, ug/l	Effluent, ug/l
Phenol*	17	17
Bis(2-ethylhexyl) Phthalate	23	14
Arsenic	39	83
Copper	110	120
Cyanide	240	260
Zinc	190	400

* represents total of all toxic pollutant phenolics

The following pollutants were detected at less than 10 ug/l in the influent and effluent: Ethylbenzene; Fluoranthene; Di-n-butyl Phthalate; Benzo(a)Anthracene; Benzo(a)Pyrene; Benzo(k)Fluoranthane; Anthracene; Toluene; Antimony.

This case discusses the results at Mill O, a Subcategory 2 Wool Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

During the pilot plant testing of the candidate mode treatment technologies at this mill, samples were collected over a typical 72-hour period of operation to evaluate the effectiveness of the technologies in removing toxic pollutants. Multi-media filtration was part of two modes of treatment, and testing was such that one unit could be evaluated independently. Data on the effectiveness are presented below.

Toxic Pollutant Treatability at Mill O
Influent and Effluent to Multi-Media Filter*

Toxic Pollutant	Influent** Min	Max	n	Effluent** Min	Max	n
Methylene Chloride	46	46	1	47	47	1
Bis(2-ethylhexyl) Phthalate	230	760	3	16	80	3
Chromium	158	206	3	78	101	3
Copper	T	14	3	105	130	3
Lead	22#	22#	3	22#	22#	3
Nickel	36#	36#	3	36#	36#	3
Thallium	50#	50#	3	50#	50#	3
Zinc	639	1280	3	371	594	3

* Unit 1
** concentrations in ug/l
n number of samples
T trace
reported as "less than" value

The following pollutants were detected at less than 10 ug/l in the influent and effluent: Acrylonitrile; Benzene; 1,2,4-Trichlorobenzene; 2,4,6-Trichlorophenol; Parachlorametacresol; Chloroform; 1,2-Dichlorobenzene; Ethylbenzene; Fluoranthene; Naphthalene; N-nitrosodi-n-propylamine; Pentachlorophenol; Phenol; Di-n-butyl Phthalate; Diethyl Phthalate; Phenanthrene; Pyrene; Tetrachloroethylene; Toluene; Trichloroethylene; Antimony; Arsenic; Beryllium; Cadmium; Cyanide; Mercury; Selenium; Silver.

b. Hyperfiltration/Ultrafiltration

Hyperfiltration (reverse osmosis) is a physical separation process that relies on applied pressure (greater than osmotic pressure) to force flow through a semi-permeable membrane (permeable to water but not dissolved materials of a specific molecular size). The process is capable of removing suspended particles and substantial fractions of dissolved impurities, including organic and inoganic materials. The membranes are designed so that water and species smaller in size than the rejection level of the particular membrane pass through while larger species are rejected. The process results in two effluents, one relatively pure, and the other containing the concentrated substances.

The membrane is the most important aspect of the reverse osmosis systems. Those most widely used are manufactured from a mixture of cellulose acetate, acetone, formamide, and magnesium perchlorate. Non-cellulose synthetic polymer membranes have also been developed and are commercially available; however, these are more often applicable in untrafiltration systems. The most common commercially available hyperfiltration systems include the tubular, spiral wound, and hollow fine fiber. The tubular system has a typical membrane area per unit volume of 20 ft^2/ft^3 and the membrane is situated along the inner wall of a 1/2-inch diameter tube. The spiral wound system utilizes a number of flat membranes separated by porous spacers and rolled into a spiral; these systems typically provide 250 ft^2 of membrane surface per ft^3 of volume. The hollow fiber system utilizes microscopic fibers that are essentially tiny, thick-walled tubes. Pressure is applied from the outside of the tubes and the filtrate (pure effluent) flows into the tubes. The hollow fiber system can provide from 2000 to 5000 ft^2 of membrane surface per ft^3 of volume. The tubular system is easiest to clean, or replace, and is usually employed in wastewater applications.

Hyperfiltration systems usually operate at a pressure of 300 to 1,500 psi and have a flux rate on the order of 10 gal/day/ft^2. They generally require extensive pretreatment (pH adjustment, filtration, chemical precipitation, activated-carbon adsorption) of the waste stream to prevent rapid fouling or deterioration of the membrane surface.

Ultrafiltration is similar to hyperfiltration and relies on a semi-permeable membrane and an applied driving force to separate suspended and dissolved materials from wastewater. The membranes used in ultrafiltration have pores large enough to eliminate osmotic pressure as a factor and, therefore, allow operation at pressures as low as 5 to 10 psi. Sieving is the predominant mechanism of removal, and the process is usually applicable for removal of materials above a molecular weight of 500 that have very small osmotic pressure at moderate concentration. Because of the larger pore sizes, flux rates for ultrafiltration are on the order of 20 to 50 gal/day/ft^2. The systems have been used for removal or concentration of macromolecules such as proteins, enzymes, starches, and other organic polymers.

<u>Industry Application</u>. None of the textile mills surveyed during this study report the use of hyperfiltration or ultrafiltration in their end-of-pipe wastewater treatment systems.

<u>Literature/Research</u>. Both hyperfiltration and ultrafiltration of textile wastewater has been studied by EPA and others for several years. A research project (71) funded by the EPA Office of Research and Development investigated the feasibility of hyperfiltration membranes for the renovation of composite textile dyeing and finishing wastewater from a Subcategory 4a Woven Fabric Finishing mill. The processing at the mill included piece dyeing of upholstery fabrics made of cotton, rayon, and nylon. The general conclusion of the study is that the product water quality is satisfactory for direct reuse in

all dyeing and finishing operations at the facility. The results of the study are available for information on equipment performance and projected treatment cost.

A second research project (72), also funded by the EPA Office of Research and Development, investigated hyperfiltration for renovation of composite wastewater at eight textile finishing plants. The objective of the study was to obtain results that when combined with the results obtained from the project noted above (71) would permit a feasible assessment of hyperfiltration as a general treatment technology for the textile industry. The study involved the measurement of membrane performance with minimum pretreatment, the evaluation of reuse of both the purified product water and the concentrated residue, and the determination of the treatability of the concentrate by conventional means. The general conclusions of the study are that the product water is satisfactory for reuse in scouring, bleaching, dyeing, and finishing and that the residual concentrate is treatable by conventional treatment equivalent to that used at each facility for treating the composite wastewater. The results of the investigations are available for information on equipment performance and projected treatment cost.

Based on the finding of the above hyperfiltration studies, a full-scale demonstration project has been funded by EPA and is currently in the design and construction phase.

Research has been conducted, and a full-scale ultrafiltration system is in place, for recovery of synthetic sizes from scouring wastes.

c. Dissolved Air Flotation

Dissolved air flotation is a physical separation operation that is used to separate solid or liquid particles from a liquid phase. A portion of the flow is pressurized to 40 to 50 psi in the presence of sufficient air to approach saturation. The pressurized air-liquid mixture is released in a flotation unit through which the remaining waste stream flows. The entrained air is released as fine bubbles that attach to the particulate matter. The buoyant force of the gas bubbles causes the particles to rise to the surface where they are skimmed off.

The performance of a flotation unit is related to the air-solids ratio, which is defined as pounds of air released per pound of solids in the influent waste. A typical range of the air to solids ratio is 0.01 to 0.1.

The primary variables for flotation design are the quantity of air used, the influent solids and/or oil concentration, and the overflow rate. When the flotation process is used primarily for clarification, a detention period of 20 to 30 minutes is adequate for separation and concentration. Rise rates of 1.5 to 5.0 gpm/sq ft are commonly employed. (73)

The principal components of a dissolved air flotation system are a pressurizing pump, air injection facilities, a retention tank, a back pressure regulating device, and a flotation unit. The pressurizing pump creates an elevated pressure to increase the solubility of air. Air is usually added through an injector on the suction side of the pump. Of the total air induced, 30 to 45 percent will usually be dissolved.

Chemicals such as aluminum and iron salts and activated silica are commonly used in dissolved air flotation to increase the flocculent structure of the floated particles and hence facilitate the capture of gas bubbles. A variety of organic chemicals (polymers) may also be employed to change the nature of either the air-liquid interface or the solid-liquid interface, or both.

Industry Application. Five of the mills surveyed report that air flotation is employed in their waste treatment systems. Two are direct dischargers, two are indirect dischargers, and one practices complete recycle. One of the direct dischargers separates print pastes from a segregated print department discharge. The other direct discharger reclaims indigo dyestuff for reuse from a yarn dyeing operation. One indirect discharger separates print pastes from the discharge of a sheet printing operation, and the other removes latex from a coating operation. The recycle plant separate print paste from the discharge of large woven fabric printing operation. Historical monitoring data are not available to demonstrate the effectiveness of the air flotation units alone.

Literature/Research. During this study, sampling was conducted at one of the mills noted above to provide information on the effectiveness of air flotation. The results are discussed in the following case.

Case 1

This case discusses the results at a Subcategory 4a Woven Fabric Finishing mill that performs flat bed and rotary screen printing to produce sheets, towels, and bedspreads. Rotary screening printing accounts for approximately 90 percent of the production, which was reported as 30,000 kg/day (approximately 65,000 lb/day). The processing operations result in a water usage of 19.2 l/kg (2.3 gal/lb) and a wastewater discharge of 570 cu m/day (150,000 gpd).

Wastewater treatment at this mill consists of equalization (small holding tank), grit removal, coarse screening, chemical addition (alum and caustic), fine screening, (SWECO vibrating screens), chemical addition (cationic polymer) and flocculation, dissolved air flotation (300 gpm), biological aeration (2 lagoons in series with a total volume of 1.64 mil gal), disinfection (chlorine), secondary clarification (reactor/clarifier in which alum, caustic, and anionic polymer are added), and dual-media gravity filtrations (sand and carbon). Aeration detention time is approximately 170 hours, and air is provided by surface aerators at a power-to-volume ratio of approximately 18 hp/mil gal. The discharge from the treatment plant is recycled for reuse in the printing operations.

Samples were collected (see Appendix D for sampling procedures) over a typical 48-hour period of operation at the bar screen prior to the air flotation unit, at the Parshall flume prior to the aeration basins, at the chlorine contact chamber following aeration, and at the effluent from the dual-media filters. The results presented below demonstrate the effectiveness of the dissolved air flotation unit in treating conventional, non-conventional, and toxic pollutants.

Conventional and Non-Conventional Pollutant Treatability
Influent and Effluent to Dissolved Air Flotation Unit*

Pollutant Parameter	Influent	Effluent
BOD_5, mg/l	400	200**
COD, mg/l	1050	725
TSS, mg/l	195	32
Phenols, ug/l	92	26
Sulfide, ug/l	200**	200**

* average of two 24-hour samples
** reported as "less than" value

Toxic Pollutant Treatability
Influent and Effluent to Dissolved Air Flotation Unit*

Toxic Pollutant	Influent, ug/l	Effluent, ug/l
Benzene	18	12
1,1,1-Trichloroethane	11	T
Ethylbenzene	460	160
Methyl Chloride	26	30
Naphthalene	250	ND
Pentachlorophenol	37	30
Phenol	94	26
Bis(2-ethylhexyl) Phthalate	570	45
Di-n-butyl Phthalate	13	ND
Toluene	320	132
Copper	323	81
Lead	14	ND
Nickel	28	32
Thallium	T	14
Zinc	25	T

* average of two 24-hour samples
ND not detected
T trace

The following pollutants were detected at less than 10 ug/l in the influent and effluent: 1,2-Dichloroethane; Chloroform; Tetrachloroethylene; Beryllium; Cadmium; Chromium; Cyanide; Mercury; Selenium; Silver; Thallium.

d. Stripping

Stripping here refers to the removal of relatively volatile components from a wastewater by the passage of air, steam, or other gas through the liquid. For example, ammonia-nitrogen has been removed from high-pH municipal wastewater by air stripping in a limited number of applications. The exhaust gas is vented to the atmosphere without treatment in most cases. Steam stripping of ammonia-rich water followed by recovery of the ammonia as ammonium salt in an acidic absorbing liquid is a newer process under development. (74, 75) Stripping odorous substances from kraft pulp mill waste streams by steam provides another example (76).

Stripping of certain volatile toxic pollutants from textile mill wastewaters under controlled conditions that prevent release to the atmosphere is theoretically a potential treatment process. Serious questions about the economic feasibility must be addressed, however, because of the relatively low concentrations typically present. At this time, there is no information about design criteria, effectiveness, or costs for any treatment systems, either in use in the textile industry or transferrable from other applications, that are available for stripping volatile pollutants from textile mill wastewaters.

e. Electrodialysis

Electrodialysis is a membrane separation process that is employed to separate ionic components from a liquid phase. The process makes use of an induced electric current that causes migration of cations toward a negative electrode and migration of anions toward a positive electrode. Separation is accomplished by alternately placing cation- and anion-selective membranes across the current path. Because of the alternate spacing, cells of concentrated and dilute solutions are formed. Electrodialysis shares the same operating difficulties as hyper- and ultra-filtration systems in that pretreatment is usually necessary to prevent rapid fouling of the membranes.

Industry Application. There are currently no known textile mills that employ electrodialysis as part of their waste treatment systems. Since the process primarily is applicable to the separation of soluble inorganic ions, it has not been given much consideration except in the case of wastewater renovation for reuse.

5. Sorption Systems

a. Activated Carbon Adsorption

Activated carbon adsorption is a physical separation process in which substances in water are removed on the surface of highly porous carbon particles. Various raw materials are used in the production of activated carbon. The carbonized material is activated, usually by steam, to remove tars and other impurities and open up and enlarge the pores. Pore size depends, in part, upon the source material and different activated carbons are available for different applications, gaseous and liquid systems, for example. Pore size is increased through regeneration, also. (77)

The primary removal mechanism of activated carbon is termed "adsorption," the physical attraction and accumulation of the removed material on the surface of the carbon. Activated carbons typically have surface areas of 500 to 1,400 square meters per gram.

Many factors have been identified as important in describing the adsorption of materials on activated carbon. It is not appropritae for this discussion to include all of the factors relating to the nature of the carbon and its surface area, particle size, pore size, etc. Instead, the focus is on the materials in the water that are to be adsorbed. General information has been developed about the molecular structure of compounds, in relation to adsorbability, in terms of both polarity and degree of ionization (78). Molecular structure, of course, is reflected also in the solubility of the compound and materials that are less attracted to water tend to be more attracted to activated carbon surfaces.

In general, molecules are more readily adsorbed than ionized compounds. The aromatic compounds tend to be more readily adsorbed than the aliphatics, and larger molecules more readily adsorbed then smaller ones, although extremely high molecular weight materials can be too large to penetrate the pores in the carbon. Treatment of wastes with carbon is generally considered for organic rather than inorganic components, although metals and other inorganics may be adsorbed on carbon surfaces or on organic solids that are removed in granular carbon filters.

The concentration level of the material is important in several ways including competition for sites with other organic materials in the water and also displacement of molecules already adsorbed by compounds more favored by the carbon. A very important consideration relating to concentration is that the behavior of the toxic pollutants has not yet been widely studies to any degree at the very low concentrations that are likely in most wastewaters. The effects of competition with other organics when the compounds of interest are at extremely low levels is almost totally speculative at this time. A last, very important factor in adsorption phenomena is the pH of the solution. Usually, the lower the pH of the solution, the greater the adsorption of many materials although, again, it depends upon the type of material being taken up.

As pointed out by Ford (79) and others, adsorption with activated carbon cannot be regarded as a universal panacea capable of removing all types of organics under all conditions. The process has limitations and must be evaluated for particular situations. Preliminary treatment of the wastewater, such as pH adjustment, coagulation, or chemical oxidation may improve the adsorbability of some pollutants.

There are two forms of activated carbon in common use, granular and powdered. To date, the granular form has been preferred for most wastewater applications because it can be readily regenerated. Regeneration of powdered activated carbon by steam is currently under development. Granular carbon is commonly employed in columns operated in series. The columns may be operated downflow packed bed, upflow packed bed, or upflow expanded bed. Although the upflow expanded bed theoretically is the best alternative due to its ability to process more turbid wastewaters without clogging, operational difficulties have limited its development. The upflow packed bed offers an important advantage. The column can be operated continuously, with the exhausted carbon being removed at the bottom of the column with virgin, or regenerated, carbon added at the top. This eliminates the need for an auxiliary column for use when an exhausted column is being serviced.

Spent carbon is commonly regenerated thermally at 1500°F in a multiple hearth furnace in the presence of steam. Here, the adsorbed organics are oxidized to gasses in the form of either CO or CO^2. Some elemental carbon is lost in the process, but this is usually limited to less than 10% by weight. After regeneration, the carbon is returned to the columns for reuse.

An aspect of granular carbon columns that is currently receiving attention is the role and possible benefits of biological growths on the carbon surfaces. In some applications, much of the removal has been found to result from biodegradation rather than adsorption.

Powdered activated carbon (PAC) use in wastewater treatment applications has increased rapidly in the past decade. Various application points in the treatment sequence have been used, with the activated sludge aeration tank being the most common. To date, the spent carbon is discarded without regeneration in most systems. This amounts, in effect, to a transfer of the removed pollutants from the water to the carbon and biorefractory materials remain intact in the sludge or other residue containing the spent carbon. Treatment using powdered activated carbon is discussed as a separate topic below.

Industry Application. Only one of the mills surveyed in this study reports the use of granular activated carbon in its waste treatment system. Several additional textile mills also are using activated carbon as part of closed (recycle) systems for at least a part of their discharge on the characteristics of these systems. However, information was not obtained during this study.

Literature/Research. Activated carbon adsorption has received considerable attention with regard to treating industrial wastewaters. Much of the information available on textile waste has to do with treatment of individual waste streams to allow water reuse. The most applicable data available on end-of-pipe treatment are those obtained during the EPA/Industry field studies. The available results of these studies are discussed below.

EPA/Industry Field Studies. In a joint research effort between EPA and the textile industry (ATMI, NTA, and CRI), pilot plant studies were conducted during 1977 and 1978 at 19 textile mills to evaluate the effectiveness of alternative advanced wastewater treatment technologies. The studies were performed with secondary clarifier effluent from treatment systems employing the recommended BPT level of treatment. One of the alternatives was granular activated carbon adsorption using three carbon columns operated in series in the downflow mode. Each column is 7.75 ft in height and 7.5 in. in diameter. They are constructed of Schedule 80 PVC pipe and have a carbon capacity of 40 lbs, allowing for sufficient expansion volume during backwashing. Depanding on the results of isotherm testing, either Westvaco,ICI, or Hydrodarco granular carbon was utilized. The available results of the activated carbon studies during the candidate process evaluations are discussed in the following cases.

Case 1

This case discusses the results at Mill D, a Subcategory 4c Woven Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

The experimental testing was performed on secondary clarifier effluent prior to chlorination. Two candidate modes were tested, and both utilized activated carbon. One mode consisted of multi-media filtration followed by activated carbon; the other mode additionally included ozonation. The operating characteristics and data on the effectiveness of activated carbon adsorption are presented below.

Conventional and Non-Conventional Pollutant Treatability at Mill D
Influent and Effluent to Activated Carbon Columns*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD5, mg/l	19	9	15	13	7	21
COD, mg/l	630	177	19	422	143	22
TSS, mg/l	85	100	16	23	13	21
TOC, mg/l	157	64	32	101	40	14
Color, ADMI	1070	-	-	825	239	14

* Westvaco WV-L activated carbon with an empty bed retention time of 45 minutes.
$\bar{x}$ mean
SD standard deviation
n number of samples

Case 2

This case discusses the results at Mill DD, a two-facility complex that performs woven fabric and stock & yarn finishing. A Low-Water-Use Processing operation (griege mill) also is associated with this complex. A description of the manufacturing operations and wastewater treatment at this facility is provided in Appendix F.

One of two candidate modes tested at this facility included activated carbon. However, the effectiveness of activated carbon alone cannot be evaluated based on the available data.

In addition to the regular pilot plant studies at this facility, samples were collected over a typical 8-hour operating period to evaluate the effectiveness of the pilot plant technologies in removing priority pollutants. One mode tested included multi-media filtration followed by activated carbon. The surface loading rate to the filters ranged from 1 to 4 gpm/ft^2 and the carbon columns were operated at an empty bed retention time of 45 minutes. Data on the effectiveness are presented below.

Toxic Pollutant Treatability at Mill DD
Influent and Effluent to Activated Carbon Columns

Toxic Pollutant	Influent, ug/l	Effluent, ug/l
Chromium	58	130
Copper	59	42
Lead	37	35
Nickel	72	81
Silver	25	32
Zinc	190	370

The following pollutants were detected at less than 10 ug/l in the influent and effluent to the filter: Bis(2-ethylhexyl) Phthalate; Diethyl Phthalate; Dimethyl Phthalate; Toluene; Arsenic; Cadmium.

Case 3

This case discusses the results at Mill B, a Subcategory 2 Wool Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

Secondary clarifier effluent prior to chlorination was used in the pilot plant tests at this mill. One candidate mode included activated carbon columns and data on the effectiveness are presented below.

Conventional and Non-Conventional Pollutant Treatability at Mill B
Influent and Effluent to Activated Carbon Columns*

	Influent			Effluent		
Pollutant Parameter	$\bar{x}$	SD	n	$\bar{x}$	SD	n
BOD_5, mg/l	31	1.4	9	16	12	9
COD, mg/l	174	72	9	26	22	9
TSS, mg/l	2	3	9	1	1	9
TOC, mg/l	65	29	9	15	8	9

* ICI Hydrodarco activated carbon with an empty bed retention time of 30 minutes (9/6 - 9/13/77).
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill B
Influent and Effluent to Activated Carbon Columns*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD5, mg/l	23	-	1	11	-	1
COD, mg/l	157	124	3	21	4	3
TSS, mg/l	31	29	3	5	4	3
TOC, mg/l	69	38	3	17	2	3

* ICI Hydrodarco activated carbon with an empty bed retention time of 28 minutes (9/11 - 9/12/77).
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill B
Influent and Effluent to Activated Carbon Columns*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD5, mg/l	20	10	9	8	7	9
COD, mg/l	203	54	9	40	12	9
TSS, mg/l	15	23	9	2	2	9
TOC, mg/l	41	16	4	18	2	5

* ICI Hydrodarco activated carbon with an empty bed retention time of 25 minutes (9/13 - 9/21/77).
$\bar{x}$ mean
SD standard deviation
n number of samples

In addition to the regular pilot plant studies at this facility, samples were collected over a 24-hr period to evaluate the effectiveness of the candidate mode in removing toxic pollutants. The candidate mode tested included the reactor/clarifier followed by multi-media filtration followed by carbon adsorption. The reactor/clarifier was loaded at a rate of 400 gpd/ft^2 with 35 mg/l alum as (Al^{+3}) added as a coagulant, the multi-media filter was loaded at a rate of 5.4 gpm/ft^2, and the carbon columns were operated at an empty bed retention time of 25 to 30 minutes. Data on the effectiveness of the activated carbon columns are presented below.

Toxic Pollutant Treatability at Mill B
Influent and Effluent to Activated Carbon Columns

Toxic Pollutant	Influent, ug/l	Effluent, ug/l
1,2,4-Trichlorobenzene	94	ND
Pentachlorophenol	10	ND
Bis(2-ethylhexyl) Phthalate	14	5
Toluene	12	ND
Antimony	12	6
Arsenic	103	ND
Cadmium	105	13
Chromium	41	29
Copper	118	51
Lead	116	12
Nickel	73	82
Silver	156	151
Zinc	5890	5960

ND not detected

The following pollutants were detected at less than 10 ug/l in the influent and effluent: 1,2-Dichlorobenzene; 2,4-Dimethylphenol, N-nitrosodiphenylamine; Phenol; Benzo(a)Pyrene.

Case 4

This case discusses the results at Mill P, a Subcategory 4c Woven Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

One candidate mode tested included filtration with precoagulation followed by activated carbon adsorption. Testing was performed on the secondary clarifier effluent prior to chlorination. The operating characteristics and data on the effectiveness of the carbon columns are presented below.

Conventional and Non-Conventional Pollutant Treatability at Mill P
Influent and Effluent to Activated Carbon Columns*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD5, mg/l	11	-	2	6	-	2
COD, mg/l	118	-	2	57	-	2
TSS, mg/l	17	-	2	19	-	1
TOC, mg/l	27	-	2	7	-	2
Color, ADMI	161	-	1	39	-	1

* Westvaco WL-L activated carbon with an empty bed retention time of 45 minutes.
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill P
Influent and Effluent to Activated Carbon Columns*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD5, mg/l	38	-	1	15	-	1
COD, mg/l	130	-	1	70	-	1
TSS, mg/l	10	-	1	-	-	1
TOC, mg/l	25	-	1	11	-	1
Color, ADMI	162	-	1	44	-	1

* Westvaco WV-1 activated carbon with an empty bed retention time of 23 minutes.
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill P
Influent and Effluent to Activated Carbon Columns*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD5, mg/l	9	6	4	8	5	5
COD, mg/l	98	15	5	93	32	5
TSS, mg/l	21	15	5	-	-	-
TOC, mg/l	23	4	5	12	3	5
Color, ADMI	141	28	3	56	8	3

* Westvaco WV-1 activated carbon with an empty bed retention time of 23 minutes.
$\bar{x}$ mean
SD standard deviation
n number of samples

Case 5

This case discusses the results at Mill Q, a Subcategory 5b Knit Fabric Finishing mill. This facility is actually two separate Knit Fabric Finishing mills that discharge to a common treatment plant. A description of the manufacturint operations and wastewater treatment at these mills is provided in Appendix F.

One candidate mode tested included the reactor/clarifier followed by multi-media filtration followed by activated carbon adsorption. Testing was performed on the secondary clarifier effluent prior to chlorination, with and without a precoagulant added. The operating characteristics and data on the effectiveness of the activated carbon columns during the testing are presented below.

Conventional and Non-Conventional Pollutant Treatability at Mill Q
Influent and Effluent to Activated Carbon Columns*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD5, mg/l	4	7	6	1.7	0.5	6
COD, mg/l	202	10	6	74	7	6
TSS, mg/l	4.5	2.6	6	2.3	0.8	6
TOC, mg/l	-	-	-	-	-	-
Color, ADMI	205	45	5	137	26	4

* Westvaco WV-L activated carbon with an empty bed retention time of 22 minutes.
$\bar{x}$ mean
SD standard deviation
n number of samples

Conventional and Non-Conventional Pollutant Treatability at Mill Q
Influent and Effluent to Activated Carbon Columns*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD5, mg/l	4.4	1	14	2.1	1.6	14
COD, mg/l	208	17	14	70	25	14
TSS, mg/l	4	1.5	14	2.5	0.8	14
TOC, mg/l	22	1.7	3	13.7	1.5	3
Color, ADMI	250	14	6	111	66	7

* Westvaco WV-L activated carbon with an empty bed retention time of 30 minutes.
$\bar{x}$ mean
SD standard deviation
n number of samples

In addition to the regular pilot plant studies at this facility, samples were collected over a typical 48-hour period of operation to evaluate the effectiveness of the pilot plant technologies in removing toxic pollutants. One mode of operation tested was multi-media filtration followed by activated carbon adsorption. Samples were collected before and after the mode only. The filters were loaded at a rate of 3 gpm/ft^2 and the carbon columns were operated at an empty bed retention time of 22 minutes. Data on the effectiveness of this mode are presented below.

Toxic Pollutant Treatability at Mill Q
Influent and Effluent to Multi-Media Filter - Activated Carbon Columns*

Toxic Pollutant	Influent**			Effluent**		
	Min	Max	n	Min	Max	n
Bis(2-ethylhexyl) Phthalate		15	1#		58	1#
Tetrachloroethylene		17	1		ND	1
Antimony	662	684	2	655	709	2
Chromium	27	36	2	18	21	2
Copper	102	106	2	42	51	2
Lead		48	1	52	65	2
Selenium		ND	2	44	44	2
Silver		13	1	18	21	2
Zinc	47	50	2	65	72	2

* Samples collected around candidate mode of operation; each sample represents 24-hour period.
** concentrations in ug/l
# composite sample collected over 48-hour period
n number of samples
ND not detected

The following were detected at less than 10 ug/l in the influent and effluent: 2-Nitrophenol; Cadmium; Mercury.

Case 6

This case discusses the results at Mill V, a Subcategory 4c Woven Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

The candidate mode selected for Mill V consisted of the reactor/clarifier followed by multi-media filtration followed by activated carbon adsorption. Testing was performed on secondary clarifier effluent prior to chlorination. The operating characteristics and data on the effectiveness of the activated carbon columns during the testing are presented below.

Conventional and Non-Conventional Pollutant Treatability at Mill V
Influent and Effluent to Activated Carbon Columns*

Pollutant Parameter	Influent $\bar{x}$	Influent SD	Influent n	Effluent $\bar{x}$	Effluent SD	Effluent n
BOD_5, mg/l	2.5	1.2	14	1.2	0.3	14
COD, mg/l	331	31	14	176	58	14
TSS, mg/l	20	8	14	20	9	14
TOC, mg/l	62	8	14	36	10	14
Color, ADMI	283	49	11	85	20	12

* Westvaco WV-L activated carbon with an empty bed retention time of 45 minutes.
$\bar{x}$ mean
SD standard deviation
n number of samples

In addition to the regular pilot plant studies at this facility, samples were collected over a 24-hour period to evaluate the effectiveness of the candidate mode in removing toxic pollutants. The mode included the reactor/clarifier, multi-media filters, and activated carbon columns. The reactor/clarifier was operated at a surface loading rate of 400 gpd/ft^2 with a coagulant dosage of 40 mg/l alum (Al^{+3}). The multi-media filters were loaded at a rate of 3.0 gpm/ft^2, and the carbon columns were operated at 0.46 gpm (empty bed retention time of 45 minutes). Data on the effectiveness of the activated carbon columns are presented below.

Toxic Pollutant Treatability at Mill V
Influent and Effluent to Activated Carbon Columns

Toxic Pollutant	Influent, ug/l	Effluent, ug/l
Pentachlorophenol	12	not detected
Bis(2-ethylhexyl) Phthalate	trace	11
Antimony	136	116
Chromium	14	14
Copper	25	35
Lead	64	64
Silver	77	91
Zinc	234	83

The following pollutants were detected at less than 10 ug/l in the influent and effluent: 1,2-Dichlorobenzene; Di-n-butyl Phthalate; Anthracene; Cadmium; Nickel.

Case 7

This case discusses the results at Mill W, a Subcategory 5b Knit Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

One candidate mode tested included multi-media filtration followed by activated carbon adsorption. Testing was performed on secondary clarifier effluent prior to chlorination. The operating characteristics and data on the effectiveness of the activated carbon columns are presented below.

Conventional and Non-Conventional Pollutant Treatability at Mill W
Influent and Effluent to Activated Carbon Columns*

	Influent			Effluent		
Pollutant Parameter	$\bar{x}$	SD	n	$\bar{x}$	SD	n
BOD_5, mg/l	3.4	1.2	17	1.5	1	17
COD, mg/l	55	7	17	19	4	17
TSS, mg/l	9.5	4.7	17	2	1	18
TOC, mg/l	11	3.3	16	2.9	3.5	16
Color, ADMI	118	42	16	29	13	15

* Westvaco WV-L activated carbon with an empty bed retention time of 45 minutes.
$\bar{x}$ mean
SD standard deviation
n number of samples

In addition to the regular pilot plant studies at Mill W, daily samples were collected during the operation of each candidate mode to evaluate the effectiveness of the modes in treating toxic pollutants. The operating characteristics of the multi-media filtration/activated carbon mode were a 7 gpm/ft² loading rate through the filters and an empty bed retention time of 45 minutes for the carbon columns. Data on the effectiveness of the activated carbon columns are presented below.

Toxic Pollutant Treatability at Mill W
Influent and Effluent to Activated Carbon Columns

Toxic Pollutant	Influent* Min	Influent* Max	Influent* n	Effluent* Min	Effluent* Max	Effluent* n
Chloroform	ND	7	7	ND	56	7
Bis(2-ethylhexyl) Phthalate	11	42	7	2	407	7
Antimony	479	888	7	588	848	6
Copper	9	27	7	4**	24	7
Lead	28	81	7	22**	87	7
Nickel	34	137	7	36**	120	7
Silver	5**	41	7	5**	38	7
Thallium	50**	50**	1	50**	50**	1
Zinc	48	93	7	16	88	7

* concentrations in ug/l
** reported as "less than" value
n number of samples
ND not detected

Case 8

This case discusses the results at Mill E, a Subcategory 5b Knit Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

During the pilot plant testing of the candidate mode treatment technologies at this mill, samples were collected to evaluate the effectiveness of the technologies in treating toxic pollutants. One mode tested included multi-media filtration followed by activated carbon adsorption. Data on the effectiveness of the activated carbon columns are presented below.

Toxic Pollutant Treatability at Mill E
Influent and Effluent to Activated Carbon Columns

Toxic Pollutant	Influent* Min	Influent* Max	Influent* n	Effluent* Min	Effluent* Max	Effluent* n
Chloroform	ND	10	10	ND	ND	10
N-nitrosodi-n-propylamine	ND	26	10	ND	ND	10
Phenol	ND	2110	10	ND	ND	10
Bis(2-ethylhexyl) Phthalate	T	20	10	T	222	10
Antimony	10**	37	8	10**	36	8
Cadmium	T	T	8	T	22	8
Chromium	T	12	8	T	11	8
Copper	T	26	8	T	25	8
Lead	22**	27	8	22**	22**	8
Nickel	36	188	8	50	164	8
Selenium	T	10	5	T	T	5
Silver	T	68	8	T	63	8
Zinc	155	204	8	T	53	8

* concentration in ug/l
n number of samples
** reported as "less than" value
T trace
ND not detected

The following were detected at less than 10 ug/l in the influent and effluent: 1,2,4-Trichlorobenzene; 1,2-Dichlorobenzene; Ethylbenzene; Methylene Chloride; Naphthalene; Di-n-butyl Phthalate; Anthracene; Toluene; Beryllium; Cyanide.

Case 9

This case discusses the results at Mill A, a Subcategory 1 Wool Scouring facility. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

During the pilot plant testing of the candidate mode treatment technologies at this mill, samples were collected over a typical 24-hour period of operation to evaluate the effectiveness of the technologies in removing toxic pollutants. Activated carbon adsorption preceded by multi-media filtration and chemical coagulation (reactor/clarifier) was one mode of treatment, and testing was such that the activated carbon columns could be evaluated independently. Data on the effectiveness are presented below.

Toxic Pollutant Treatability at Mill A
Influent and Effluent to Activated Carbon Columns

Toxic Pollutant	Influent, ug/l	Effluent, ug/l
Phenol*	17	17
Bis(2-ethylhexyl) Phthalate	14	26
Arsenic	83	42
Copper	120	ND
Cyanide	260	40
Zinc	400	210

* representa total of all toxic pollutant phenols
ND not detected

Case 10

This case discusses the results at Mill O, a Subcategory 2 Wool Finishing mill. A description of the manufacturing operations and wastewater treatment at this mill is provided in Appendix F.

During the pilot plant testing of the candidate mode treatment technologies at this mill, samples were collected over a typical 72-hour period of operation to evaluate the effectiveness of the technologies in removing toxic pollutants. One mode tested included multi-media filtration followed by granular activated carbon adsorption. Data on the effectiveness of the activated carbon columns are presented below.

Toxic Pollutant Treatability at Mill O
Influent and Effluent to Activated Carbon Columns

Toxic Pollutant	Influent* Min	Max	n	Effluent* Min	Max	n
Acrylonitrile	ND	100**	3	ND	100**	3
Methylene Chloride	47	47	1	27	27	1
Bis(2-Ethylhexyl) Phthalate	16	80	3	T	28	3
Chromium	78	101	3	T	T	3
Copper	105	130	3	T	24	3
Lead	22**	22**	3	22**	22**	3
Nickel	36**	36**	3	36**	36**	3
Thallium	50**	50**	3	50**	50**	3
Zinc	371	594	3	331	434	3

* concentrations in ug/l
** reported as "less than" value
n number of samples
T trace
ND not detected

The following pollutants were detected at less than 10 ug/l in the influent and effluent: Benzene; 1,2,4-Trichlorobenzene; 2,4,6-Trichorophenol; Parachlorometacresol; Chloroform; 1,2-Dichlorobenzene; Ethylbenzene; Fluoranthene; Naphthalene; N-nitrosodi-n-propylamine; Pentachlorophenol; Phenol; Di-n-butyl Phthalate; Diethyl Phthalate; Anthracene; Phenanthrene; Pyrene; Tetrachloroethylene; Toluene; Trichloroethylene, Antimony; Arsenic; Beryllium; Cadmium; Cyanide; Mercury; Selenium; Silver.

b. Powdered Activated Carbon Treatment (PACT)

Powdered activated carbon treatment refers to the addition of powdered carbon to the activated sludge process. It is a recently developed process that has shown to significantly upgrade effluent quality in conventional activated sludge plants. A discussion of powdered activated carbon, in general, is provided above under "Activated Carbon." In the PACT process, the carbon concentration in the mixed liquor is generally equal to or greater than the MLSS level. The carbon and adsorbed substances are discarded as part of the biological sludge.

Industry Application. Three mills surveyed in this study report the use of powdered activated carbon in the treatment of their wastewater. Two mills manually add powdered carbon to their aeration basins and try to maintain a specific concentration of carbon in the MLSS. The other mill operates a semi-continuous system in which raw dyehouse wastewater is pumped to a tank containing a designated amount of Dicalite (powdered carbon), mixed to form a slurry, and pumped through a filter press. The filter cake is discarded as solid waste. The operation and effectiveness of one continuous system and the semi-continuous system are discussed as case studies under "Literature/Research."

Literature/Research. Bench-scale laboratory studies have been conducted by Engineering Science (80) on the wastewaters from 10 textile finishing mills and the results are presented later in this section. The treatment process at one of the textile mill reporting full-scale use of powdered activated carbon addition to the activated sludge process (PACT) and the semi-continous system treating raw textile wastewater were sampled during the verification program. The results of these studies are presented in the following cases.

Case 1

This case discusses the field sampling at a Subcategory 5a Knit Fabric Finishing mill that knits, scours, and dyes synthetic bolt cloth of polyester and acetate fiber. Pressure piece dyeing with dispersed dyes is performed on the total production and 20 percent of the production is scoured. During the field sampling, wastewater flow rate averaged 984 cu m/day (260,000 gpd).

Wastewater treatment at this mill consists of fine screening (vibratory), equalization (mixed with nitrogen added as nutrient), biological aeration (two basins operated in series with powdered activated carbon added to the first basin), secondary clarification, sand filtration, disinfection (chlorine), and post aeration. Total detention time in the aeration basins is approximately 48 hours, and air is provided by surface aerators at a power-to-volume ratio of approximately 80 hp/mil gal. The results below demonstrate te effectiveness of the PACT process in treating conventional, non-conventional, and toxic pollutants.

Conventional and Non-Conventional Pollutant Treatability
Before and After Activated Sludge Process

Pollutant Parameter	Biological Influent*	Clarifier Effluent** Min	Max	n
COD, mg/l	1744	154	254	3
TSS, mg/l	204	44	60	3
Phenol, ug/l	34	3	15	3
Sulfide, ug/l	50	8	20	3
Color, ADMI	158	75	89	3

* 72-hour composite sample
** 24-hour composite samples

Toxic Pollutant Treatability
Before and After Activated Sludge Process

Toxic Pollutant	Biological Influent*	Secondary Clarifier Effluent** Min	Max	n
Acrolein	199	ND	87	3
Acrylonitrile	90	ND	100#	3
Chloroform	ND	ND	5#	3
Methylene Chloride	30	ND	28	3
Bis(2-Ethylhexyl) Phthalate	430	8	50	3
Trichloroethylene	5	ND	41	3
Antimony	186	81	87	3
Copper	17	7	8	3
Lead	99	36	44	3
Nickel	69	54	65	3
Silver	19	14	17	3
Thallium	50#	50#	50#	3
Zinc	343	48	69	3

* 72-hour composite sample; concentrations expressed in ug/l
** 24-hour composite camples; concentrations expressed in ug/l
\# reported as "less than" value

The following pollutants were detected at less than 10 ug/l in the biological influent and secondary clarifier effluent: Benzene; 1,2,4-Trichlorobenzene; 2,4,6-Trichlorophenol; Parachlorometacresol; 1,2-Dichlorobenzene; Ethylbenzene; Naphthalene; N-nitrosodi-n-propylamine;

Pentachlorophenol; Phenol; Anthracene; Tetrachloroethylene; Toluene; Trichloroethylene; Arsenic; Beryllium; Cadmium; Chromium; Cyanide; Mercury; Selenium.

Case 2

The case discusses the results at a Subcategory 6 Carpet Finishing facility that piece dyes and backs (jute using latex adhesive) carpet made from polyester and nylon fibers. Reported production is approximately 20,400 kg/day (45,000 lb/day) of finished carpet. The processing results in a water usage of 36.7 l/kg (4.4 gal/lb) and a wastewater discharge of 757 cu m/day (0.20 mgd).

Wastewater treatment at this facility consist of coarse screening, equalization (storage tank), mixing (wastewater and powdered activated carbon), and solids separation (filter press). The results below report the effectiveness of the system in treating toxic pollutants.

Toxic Pollutant Treatability
Influent and Effluent to Powdered Activated Carbon System

		Effluent**		
Toxic Pollutant	Influent*	Min	Max	n
Naphthalene	240	T	T	2
Phenol	67	T	T	2
Bis(2-ethylhexyl) Phthalate	400	T	T	2
Antimony	12#	140	160	2
Zinc	20	40	120	2

* composite and grab samples during a 24-hour period; concentrations expressed in ug/l
** two grab samples during 24-hour period; concentrations expressed in ug/l
# reported as "less than" value

The following pollutants were detected at less than 10 ug/l in the influent and effluent: 1,1,1-Trichloroethane; Methylene Chloride; Cadmium; Copper; Mercury.

EPA/Industry Field Studies. As part of the joint research effort between EPA and the textile industry (ATMI, NTA, and CRI), bench-scale laboratory studies were conducted on the raw wastewater (influent to the biological aeration system) at 10 of the 19 pilot plant locations to evaluate the effectiveness of powdered activated carbon treatment (PACT). Each textile mill shipped wastewater to the study laboratory each week during a six-week study period. A description of the experimental procedures employed on the waste from each mill is summarized below:

1. Three 10-liter plexiglas bioreactors were seeded with activated sludge from the study mill and a municipal/industrial treatment plant and acclimated to the textile waste.

2. Following acclimation, the residual TOC of the bioreactor effluents was established.

3. Carbon adsorption isotherms were performed on the bioreactor effluent, and based on several considerations (the effects on residual TOC, experience gained in past studies, flow of full-scale plant, sludge age, economics), a high and low carbon make-up dosage was selected.

4. Two or three types of carbons were evaluated on an isotherm level and the most effective was used in the experiments.

5. The three bioreactors were designated control (no carbon addition), high carbon, and low carbon, and were operated for approximately three weeks with carbon addition and sludge wastage each day.

6. Following the initial three-week period of operation (equilibrium period), two weeks of testing was performed to evaluate performance.

It should be stressed that the testing performed was for determination of technical feasibility and to provide an indication of the achievable effluent quality. Long-term operating characteristics and costs were not considered. The results of the studies during the final two weeks of operation are summarized in the following cases.

Case 1

This case discusses the results at Mill D, a Subcategory 4c Woven Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this facility is provided in Appendix F.

PACT Treatability Studies - Mill D*

Pollutant Parameter	Influent**			Effluent**		
	Control	High	Low	Control	High	Low
BOD_5, mg/l	1169	#	#	46	24	24
COD, mg/l	2115	#	#	556	447	390
TSS, mg/l##	4121	8514	5686	15	38	45
TOC, mg/l	624	#	#	157	105	113

* Westvaco "SA" was the selected carbon; the high and low mixed liquor carbon concentrations were 6,000 mg/l and 3,000 mg/l, respectively, with corresponding daily carbon make-up dosages of 210 mg/l and 105 mg/l.

** mean of samples collected during two-week evaluation period

\# same as control

\## influent TSS is MLSS

Case 2

This case discusses the results at Mill B, a Subcategory 2 Wool Finishing mill. A description of the manufacturing operations and wastewater treatment at this facility is provided in Appendix F.

PACT Treatability Studies - Mill B*

Pollutant Parameter	Influent**			Effluent**		
	Control	High	Low	Control	High	Low
BOD_5, mg/l	407	#	#	27	18	29
COD, mg/l	1919	#	#	148	73	107
TSS, mg/l##	2986	9774	7012	29	23	33
TOC, mg/l	461	#	#	41	38	44
Color, ADMI	71	#	#	114	64	81

* Westvaco "SA" was the selected carbon; the high and low mixed liquor carbon concentrations were 8,000 mg/l and 2,000 mg/l, respectively, with corresponding daily carbon make-up dosages of 388 mg/l and 97 mg/l.

** mean of samples collected during two-week evaluation period

\# same as control

\## influent TSS is MLSS

Case 3

This case discusses the results at Mill P, a Subcategory 4c Woven Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this facility is provided in Appendix F.

PACT Treatability Studies - Mill P*

Pollutant Parameter	Influent** Control	Influent** High	Influent** Low	Effluent** Control	Effluent** High	Effluent** Low
BOD_5, mg/l	400	#	#	8	8.5	8
COD, mg/l	572	#	#	119	82	96
TSS, mg/l##	2310	4610	4052	30	10	18
TOC, mg/l	243	#	#	57	34	42
Color, ADMI	-	-	-	324	236	293

* Westvaco "SC" was the selected carbon; the high and low mixed liquor carbon concentrations were 5,000 mg/l and 1,000 mg/l, respectively, with corresponding daily carbon make-up dosages of 608 mg/l and 122 mg/l.

** mean of samples collected during two-week evaluation period

\# same as control

\## influent TSS is MLSS

Case 4

This case discusses the results at Mill Q, a Subcategory 5b Knit Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this facility is provided in Appendix F.

PACT Treatability Studies - Mill Q*

Pollutant Parameter	Influent**			Effluent**		
	Control	High	Low	Control	High	Low
BOD5, mg/l	318	#	#	17	11	14
COD, mg/l	963	#	#	215	119	175
TSS, mg/l##	4687	6577	5435	24	24	17
TOC, mg/l	383	#	#	99	44	56
Color, ADMI	-	-	-	387	242	325

* Westvaco "SC" was the selected carbon; the high and low mixed liquor carbon concentrations were 5,000 mg/l and 1,000 mg/l, respectively, with corresponding daily carbon make-up dosages of 173 mg/l and 35 mg/l.

** mean of samples collected during two-week evaluation period

\# same as control

\## influent TSS is MLSS

Case 5

This case discusses the results at Mill E, a Subcategory 5a Knit Fabric Finishing mill. A description of the manufacturing operations and wastewater treatment at this facility is provided in Appendix F.

PACT Treatability Studies - Mill E*

Pollutant Parameter	Influent**			Effluent**		
	Control	High	Low	Control	High	Low
BOD5, mg/l	505	#	#	57	21	21
COD, mg/l	1737	#	#	1765	69	103
TSS, mg/l##	6086	8818	5978	26	28	17
TOC, mg/l	446	#	#	91	40	52
Color, ADMI	61	#	#	85	49	36

* Westvaco "SC" was the selected carbon; the high and low mixed liquor carbon concentrations were 5,000 mg/l and 2,000 mg/l, respectively, with corresponding daily carbon make-up dosages of 540 mg/l and 216 mg/l.

** mean of samples collected during two-week evaluation period

\# same as control

\## influent TSS is MLSS

Case 6

This case discusses the results at Mill A, a Subcategory 1 Wool Scouring facility. A description of the manufacturing operations and wastewater treatment at this facility is provided in Appendix F.

PACT Treatability Studies - Mill A*

Pollutant Parameter	Influent** Control	Influent** High	Influent** Low	Effluent** Control	Effluent** High	Effluent** Low
BOD_5, mg/l	2580	#	#	69	51	54
COD, mg/l	5542	#	#	543	457	563
TSS, mg/l##	2977	14837	5295	568	402	366
TOC, mg/l	1784	#	#	373	336	387
Color, ADMI	-	-	-	705	253	629

* Westvaco "SC" was the selected carbon; the high and low mixed liquor carbon concentrations were 10,000 mg/l and 2,000 mg/l, respectively, with corresponding daily carbon make-up dosages of 694 mg/l and 139 mg/l.

** mean of samples collected during two-week evaluation period

\# same as control

\## influent TSS is MLSS

Case 7

This case discusses the results at Mill O, a Subcategory 2 Wool Finishing mill. A description of the manufacturing operations and wastewater treatment at this facility is provided in Appendix F.

PACT Treatability Studies - Mill O*

Pollutant Parameter	Influent**			Effluent**		
	Control	High	Low	Control	High	Low
BOD5, mg/l	247	#	#	16	6.5	8
COD, mg/l	1098	#	#	102	33	63
TSS, mg/l##	3360	7792	4373	30	11	16
TOC, mg/l	344	#	#	30	11	23
Color, ADMI	-	-	-	105	43	66

* Westvaco "SC" was the selected carbon; the high and low mixed liquor carbon concentrations were 5,000 mg/l and 1,000 mg/l, respectively, with corresponding daily carbon make-up dosages of 125 mg/l and 25 mg/l.

** mean of samples collected during two-week evaluation period

\# same as control

\## influent TSS is MLSS

Case 8

This case discusses the results at Mill F, a Subcategory 6 Carpet Finishing facility. A description of the manufacturing operations and wastewater treatment at this facility is provided in Appendix F.

PACT Treatability Studies - Mill F*

Pollutant Parameter	Influent**			Effluent**		
	Control	High	Low	Control	High	Low
BOD5, mg/l	471	#	#	11	4	6
COD, mg/l	1454	#	#	127	40	67
TSS, mg/l##	5128	8488	6318	43	19	50
TOC, mg/l	390	#	#	57	18	35
Color, ADMI	1000	#	#	236	77	125

* ICI-KB was the selected carbon; the high and low mixed liquor carbon concentrations were 5,000 mg/l and 2,000 mg/l, respectively, with corresponding daily carbon make-up dosages of 694 mg/l and 277 mg/l.

** mean of samples collected during two-week evaluation period

\# same as control

\## influent TSS is MLSS

Case 9

This case discusses the results at Mill S, a Subcategory 7 Stock & Yarn Finishing facility. A description of the manufacturing operations and wastewater treatment at this facility is provided in Appendix F.

PACT Treatability Studies - Mill S*

Pollutant Parameter	Influent** Control	High	Low	Effluent** Control	High	Low
BOD5, mg/l	95	#	#	8.5	6	8.5
COD, mg/l	956	#	#	143	35	74
TSS, mg/l##	3168	7183	4585	4	15.7	25
TOC, mg/l	390	#	#	57	18	35
Color, ADMI	-	-	-	512	140	263

* Westvaco "SC" was the selected carbon; the high and low mixed liquor carbon concentrations were 5,000 mg/l and 2,000 mg/l, respectively, with corresponding daily carbon make-up dosages of 304 mg/l and 122 mg/l.

** mean of samples collected during two-week evaluation period

\# same as control

\## influent TSS is MLSS

Case 10

This case discusses the results at Mill Y, a Subcategory 4c Woven Fabric Finishing facility. A description of the manufacturing operations and wastewater treatment at this facility is provided in Appendix F.

PACT Treatability Studies - Mill Y*

Pollutant Parameter	Influent** Control	High	Low	Effluent** Control	High	Low
BOD5, mg/l	114	#	#	6	4	5
COD, mg/l	301	#	#	98	37	60
TSS, mg/l##	1538	4657	2070	29	60	51
TOC, mg/l	91	#	#	24	9	12
Color, ADMI	268	#	#	198	148	88

* ICI-Hydrodarco was the selected carbon; the high and low mixed liquor carbon concentrations were 5,000 mg/l and 2,000 mg/l, respectively, with corresponding daily carbon make-up dosages of 526 mg/l and 210 mg/l.

** mean of samples collected during two-week evaluation period

\# same as control

\## influent TSS is MLSS

SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECTS

This section presents detailed information about the estimated costs and resulting benefits in terms of pollutant reductions achievable through the application of selected alternative control technologies. As discussed below, cost estimates are not provided for in-plant control measures, but detailed cost:benefit information for end-of-pipe treatment technologies is given. The bases used in developing the costs for the end-of-pipe treatment technologies is presented first, followed by the estimated costs and benefits for the alternatives for representative model plants in each subcategory.

Existing mills that discharge directly to receiving waters are covered first, followed by existing indirect-discharge mills, i.e., those that discharge their wastewaters to publicly owned treatment works (POTW). The next subsections cover New Sources and address direct and indirect dischargers. Energy, sludge management, air pollution, and other non-water environmental quality considerations are also addressed.

EXISTING DIRECT DISCHARGE SOURCES

In-Plant Control Measures

The in-plant control measures that are generally available to mills in the textile industry are described in Section VII. Some of these in-plant control measures are suitable for specific subcategories, depending upon product and processes in use. In developing a treatment program for a given mill, in-depth analyses of various combinations of in-plant measures and end-of-pipe treatment technologies should be carried out by a team that includes expertise in both textile processing and pollution control. Those characteristics and constituents of the wastewater that are most troublesome and costly to treat should be identified in terms of quantities and sources within the mill. An evaluation should be made of alternative in-plant measures to eliminate, reduce, and/or segregate these materials for separate treatment. The cost analysis should include costs for management of sludges and other residues and changes in air pollution control and energy requirements, as well as the more obvious items relating to plant and process modifications, new construction, etc.

A recent report (25) listed good housekeeping, reporting of leaks, countercurrent washing, and replacing of batch with continuous process equipment as most important among steps to reduce water use in textile finishing. These steps are widely recognized and indicate the general direction that the industry is moving. However, there are no specific control measures that are clearly needed in the industry as a whole or in one or more particular subcategories.

While no specific in-plant control measures were considered for existing sources, it should not be inferred that such measures are unimportant or should be eliminated from further consideration. In-plant measures can effect savings both in manufacturing and in the costs of treatment. In the future, in-plant measures may assume a much greater role in treatment and may be instrumental in the conservation of materials and energy.

Selected End-of-Pipe Technologies

The results of detailed analyses to evaluate the cost effectiveness of various end-of-pipe treatment technologies for existing direct-discharge textile mills are summarized here. A model plant approach was used to develop the costs. Included are analyses of the several most appropriate treatment alternatives for BAT. From the questionnaire survey, it was established that the majority of the existing direct dischargers have BPT in place. For most subcategories, BPT includes screening, extended-aeration activated sludge, and secondary sedimentation with solids recycle to the aeration basin. This level of treatment was used as the base, with the alternative BAT technologies added on. Mechanical sludge dewatering is not provided at the majority of textile mill treatment plants and is not included here as part of BPT. Reported current sludge processing and disposal practices are discussed later in this section under Sludge Management.

The alternatives for each level of control are given in Table VIII-1 (see page VIII-17). Some alternatives are based on individual technologies and others on combinations of technologies. These technologies include chemical coagulation, filtration, flotation, activated carbon adsorption, and ozonation. Each of these technologies is described below.

Chemical Coagulation. This technology utilizes alum as the coagulant and includes sedimentation except for wool scouring, where dissolved air flotation is included in the treatment sequence. Sludge dewatering by vacuum filter is also included for chemical coagulation. Alum was selected because of its proven effectiveness in the industry. It is recognized that lime, iron salts, and sulfides may be more appropriate in some applications, but it is believed that the costs based on alum are representative of costs that would be experienced by individual textile mills. For the vacuum filter, the filter area was determined by using a dry solids loading rate of 19.5 kg/sq m/hr (4 lb/sq ft/hr) and an operating period of 10 hr/day. Specific conditions given below under Sludge Disposal for TSS removal were also factors in sizing vacuum filters.

Multi-Media Filtration. This technology utilizes a granular media bed with polymeric filter aids added in alternatives without prior chemical coagulation. Filter backwash is pumped to the secondary sedimentation tank. Existing sludge handling practices at mill treatment facilities are assumed to be capable of handling filter backwash solids without modification. The hydraulic loading rate is 9.78 cu m/hr/sq m (4 gpm/sq ft.)

Dissolved Air Flotation. This technology is utilized in Subcategory 1 (Wool Scouring) to remove suspended solids and oil & grease. The surface hydraulic loading rate is 163.2 cu m/day/sq m (4000 gpd/sq ft).

Activated Carbon. This technology utilizes granular carbon columns and on-site carbon regeneration for wastewater flows of greater than 450 cu m/day (0.12 mgd). Carbon for smaller flows is to be discarded after use. An exhaustion rate of 0.66 kg/cu m (5500 lb/mil gal) of water treated was assumed (26).

Ozonation. This technology utilizes on-site generation of ozone from air and is based on a generator producing 100 mg/l of ozone.

The above treatment processes, alone or in combination, are believed to provide a full range of end-of-pipe technologies for use in applying the best available technology economically achievable for control of toxic pollutants.

Investment Costs

Investment costs include installed costs of treatment components and monitoring equipment plus allowances for contingencies and engineering. For the selected technologies (chemical coagulation, filtration, dissolved air flotation, activated carbon, and ozonation), specific cost curves were developed from literature and other information (27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39). The cost information was updated by the EPA-STP and/or EPA-SCCT indexes to the 4th quarter of 1976.

Total installed costs are broken into equipment and construction fractions as follows:

Process	Equipment	Construction
Chemical coagulation	20%	80%
Filtration	20	80
Dissolved air flotation	35	65
Activated carbon	50	50
Ozonation	50	50
Vacuum filtration	35	65

A contingency allowance of 15 percent of the installed cost was used to cover unexpected costs due to local mill conditions and differences between the actual systems and those used for the cost estimates. No allowance was made for mill shutdown during construction. Engineering costs were estimated by using a percentage of installed costs plus contingencies. For a total cost of $20,000 or less, 15 percent was used. For larger projects a percentage to the nearest 0.5, from curve A in "Consulting Engineering" (40), was used.

Monitoring Equipment. The investment costs are based on collecting samples of the influent and effluent streams of the treatment plant. The sampling schedule comprises 24-hour composite samples taken at each location twice weekly for direct dischargers and once per week for indirect dischargers. For direct dischargers, grab samples are to be taken once per week of the receiving water both up- and down-stream of the discharge. Continuous monitoring of pH and flow is also provided for the influent and effluent of all treatment plants.

The equipment items include two flow meters, two primary and one backup refrigerated samplers, two pH meters, and refrigerated sample storage containers. The costs were based on equipment manufacturers' price lists (41, 42, 43).

It should be noted that the equipment described here is that required for a complete monitoring program for major direct and indirect dischargers. Existing facilities, especially larger direct discharge mills, generally have most of the equipment on hand and the investment costs incurred by them would be considerably less.

Land Costs. All of the alternative technologies have small space requirements and the acquisition of additional land should not be necessary.

Annual Costs

Capital. The cost of money was assumed to be 10 percent of the total investment.

Depreciation. Estimated lives for the components of each alternative were established and related to the investment costs to determine the estimated design life for the alternative. The installed cost plus contingencies was depreciated on a straight-line basis for the calculated life of each alternative.

Operation Labor. Estimates of the annual man-hours required to operate the various component systems were developed from the literature (30 44). A productive work value of 6.5 hr/day/man, or 1,500 hr/yr/man, was assumed (44). A rate of $15/hr was used as the total cost for wages, benefits, and payroll processing expenses. Laboratory man-hours were developed for each model plant size and the associated costs were included. It was assumed that supervisory, administrative, and clerical costs would be covered by existing personnel.

Maintenance Labor. Maintenance labor costs were developed in the same manner as operating labor costs. The annual costs of materials and parts needed to maintain each technology were developed from the literature and equipment manufacturers (30, 37, 38).

Sludge Disposal. Sludge disposal costs cover hauling dewatered sludge, and exhausted activated carbon when applicable, to an approved sanitary landfill. The hauling costs were obtained from the industry survey questionnaires and were plotted as tons/yr of sludge hauled vs dollars/ton. The costs ranged from 18 to 1 dollars/ton, decreasing with increasing tonnage. The dewatered sludge was assumed to contain 20 percent solids by weight after vacuum filtration.

Sludge disposal costs associated with chemical coagulation and multi-media filtration were developed based on the quantity of suspended solids in the waste stream and the desired degree of removal. Specific conditions were developed for both technologies by grouping similar influent waste streams. For chemical coagulation, the following conditions are represented:

Coagulation Condition	TSS Removed mg/l	Effluent TSS mg/l	Alum Added mg/l
1	3200	70	1000
2	630	70	1000
3	120	30	100
4	60	35	100
5	25	25	100

The cases developed for multi-media filtration represent the following conditions:

Filtration Condition	TSS Removed mg/l	Effluent TSS mg/l
1	40	10
2	20	10
3	5	10

Values for specific conditions were used for each technology to determine the weight of material that must be handled for each alternative.

Costs to dispose of spent activated carbon are based on hauling to a landfill. The carbon would be wet during hauling, containing its own weight of water.

Information on current sludge management practices in the industry is presented at the end of this section.

Energy and Power. Operation time for the equipment of each component of all treatment alternatives, with the exception of vacuum filtration, was assumed to be 24 hr/day and 300 days/yr. Vacuum filters were sized to operate 10 hr/day, 300 days/yr.

Annual electrical energy consumption values for the component equipment items were developed utilizing applicable technical literature (36, 41, 45, 46, 47, 48, 49) and equipment manufacturers' specifications (50). In developing the costs, all electric motors were assumed to have an efficiency of 88 percent (51) and the cost for electricity was assumed to be 2.4¢/kwh. The cost value is a typical value taken from the questionnaire responses for the southeastern region of the U.S. This region was chosen because the majority of the country's textile mills are located there (Table III-1).

Fuel oil and natural gas costs were developed from questionnaire responses and applicable technical literature (35). Costs in the southeast were again used as a basis with 23¢/therm for fuel oil and 19¢/therm for natural gas established as typical costs.

Vacuum filtration energy consumption varies with filter area. The area, or size of the filter, was found to be dependent on the specific condition, treatment alternative, and flow rate being evaluated. Energy consumption is dependent on these criteria also. Energy consumption for activated carbon varies depending on the flow and whether the exhausted carbon is regenerated or discarded. For the other technologies, consumption is based solely on flow.

Information on the relative additional energy requirements of the alternative end-of-pipe treatment technologies for selected subcategories is presented near the end of this section.

Chemicals. Alum was the coagulant of choice based on its proven effectiveness and reasonable cost, although other coagulants are used by the industry and may be more applicable in specific cases. The costs of polymeric filter aids are included whenever filtration is not preceded by chemical coagulation.

Chemical costs are based on prices quoted in the Chemical Marketing Reporter (52) for December 6 and 20, 1976. The following estimated delivered costs are used:

Alum (technical)	-	\$174 to \$185 per MT (\$158 to \$168 per ton)
Polymer	-	\$2.20 per kg (\$1 per lb)
Carbon (granular)	-	\$1.25 per kg (\$0.50 per lb)

The assumed alum dosages were 1000 mg/l for coagulation conditions 1 and 2, and 100 mg/l for conditions 3, 4, and 5. The assumed polymer dosage was 1 mg/l for all filtration conditions.

Monitoring. Monitoring costs include outside laboratory analytical charges and time for reporting results to regulatory agencies. The costs associated with collecting and delivering samples are included under operation and maintenance labor.

Separate monitoring costs were developed for direct and indirect dischargers. Direct dischargers were assumed to sample in order to comply with a discharge permit. This entails sampling influent and effluent waste streams plus the receiving water regularly. Samples for the conventional pollutants are collected twice weekly, and non-conventional pollutants are analyzed once per week. Samples for toxic pollutants are collected and analyzed semi-annually. Indirect dischargers were assumed to sample in order to comply with the local sewer ordinances. Conventional and non-conventional pollutants are measured weekly, and toxic pollutants semi-annually.

Laboratory cost estimates were based on current (January-June, 1978) commercial laboratory price lists (43, 53, 54, 55, 56, 57, 58, 59). Reporting costs were based on \$15/hr and allowed 1 hr/week for compiling data plus 8 hr/month for preparing data reports.

Annual monitoring costs are based on a complete program for major direct and indirect dischargers. As mentioned under "Monitoring Equipment," many of the larger facilities have existing programs that would result in considerably less additional cost in this area. In addition, it would not generally be necessary for smaller facilities to institute such extensive programs. The monitoring frequencies are assumed for cost estimation purposes only and are not intended to provide a model for compliance monitoring.

Cost Curves

Cost curves for the individual treatment processes, including vacuum filtration for processing sludge, are presented in Figures VIII-1 through VIII-7. The curves, which represent 4th quarter 1976 dollars (EPA-SCCT = 119), are plotted as flow (vacuum filtration is plotted as sq ft of filter area) vs dollars of total installed cost. They provide the basis for estimating the investment costs for the alternative treatment technologies when allowances for contingencies, engineering, and land are added. Figure VIII-8 is a curve for dewatered sludge hauling costs and is used to estimate annual sludge disposal expenses for each alternative.

Model Plant Costs

In selecting model plants sizes, production as well as flow was considered. Survey responses were initially grouped by subcategory and discharge type, i.e., direct and indirect. The initial groups were further broken down, generally into three groups, on the basis of production size. Average percent utilization values, which were determined from the survey responses for the mills in each group, were applied to the average production values for each group to obtain full capacity production values for typical plants. These capacities were multiplied by the median water usage rates for each subcategory to calculate a flow rate for each production group. The calculated flow rates were subsequently compared to actual reported flow rates and were found to accurately represent the mills in each subcategory.

As presented previously, five treatment processes (chemical coagulation, filtration, dissolved air flotation, activated carbon, and ozonation) have been combined in various systems to provide the alternative end-of-pipe treatment technologies. These alternatives are presented in Table VIII-1 and are discussed in greater detail in following parts of this section.

The textile mills included in the industry survey represent production values ranging from 54 to 317,333 kg/day (120 to 700,000 lb/day) and flow rates ranging from 3,784 to 29,894 cu m/day (0.001 to 7.9 mgd). Based on these ranges, eight model plant sizes were selected to represent the industry. The sizes, based on flow rate, are: 189, 416, 946, 2,271, 3,785, 5,678, 11,355, and 18,925 cu m/day (0.05, 0.11, 0.25, 0.6, 1.0, 1.5, 3.0, and 5.0 mgd). The sizes representing direct and indirect dischargers for each subcategory are given in Table VIII-2.

Cost estimates were developed for all of the selected model plant sizes shown in Table VIII-2 and forwarded to a separate contractor for use in evaluating the economic impact of possible effluent regulations on the industry. Selected model plant sizes are included in this document to illustrate the methodology used and the relative differences between the alternative technologies.

Cost Effectiveness Summaries

Model plant control cost summary sheets were developed for each model plant to provide a synopsis of the cost analysis for each alternative technology. Total investment costs, including the installed cost of each component of a given alternative, monitoring equipment, engineering, and contingencies are provided. Also, total annual

FIGURE VIII-1
CHEMICAL COAGULATION - INSTALLED COST

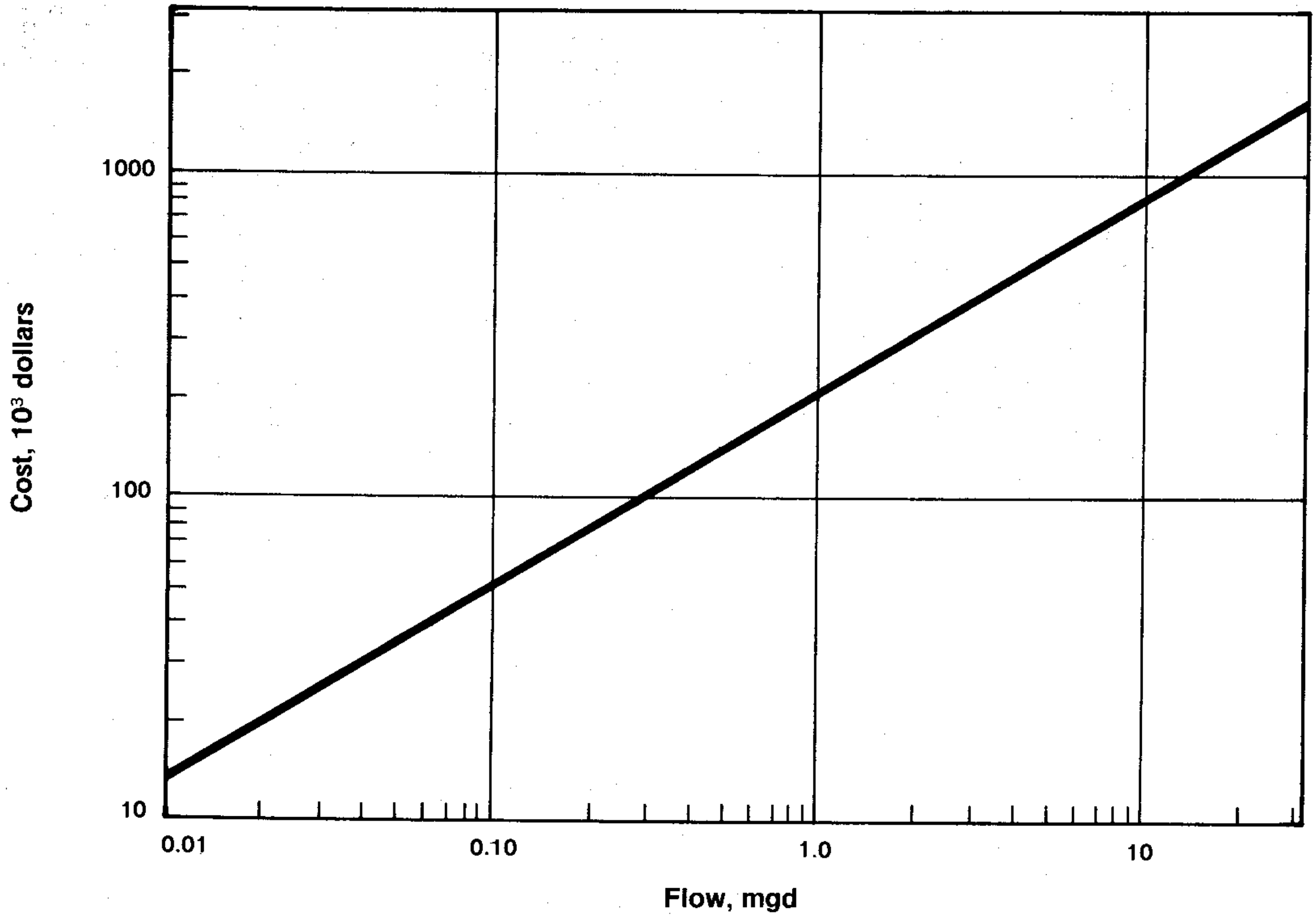


FIGURE VIII-2
DISSOLVED AIR FLOTATION - INSTALLED COST

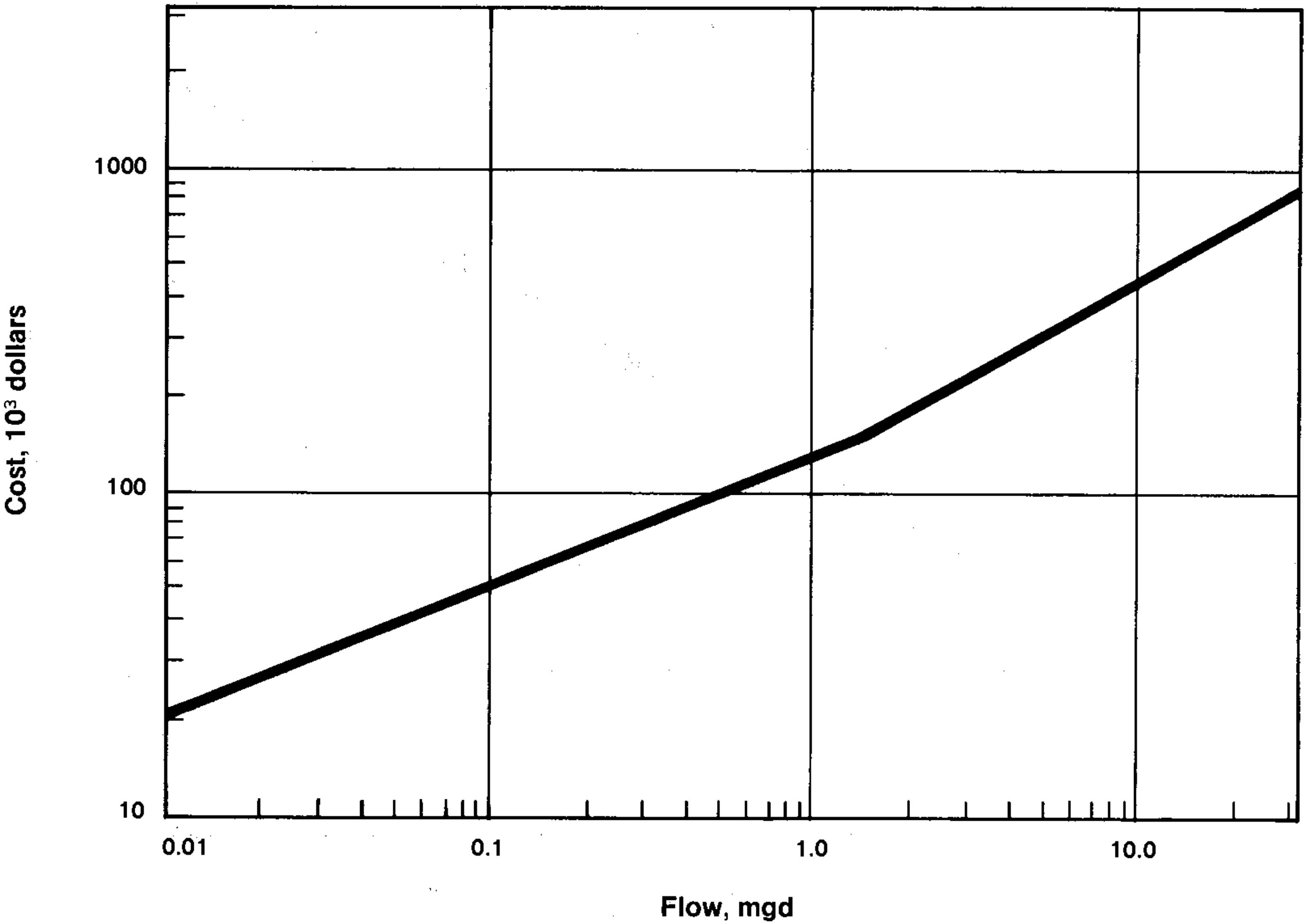


FIGURE VIII-3
MULTI-MEDIA FILTRATION - INSTALLED COST

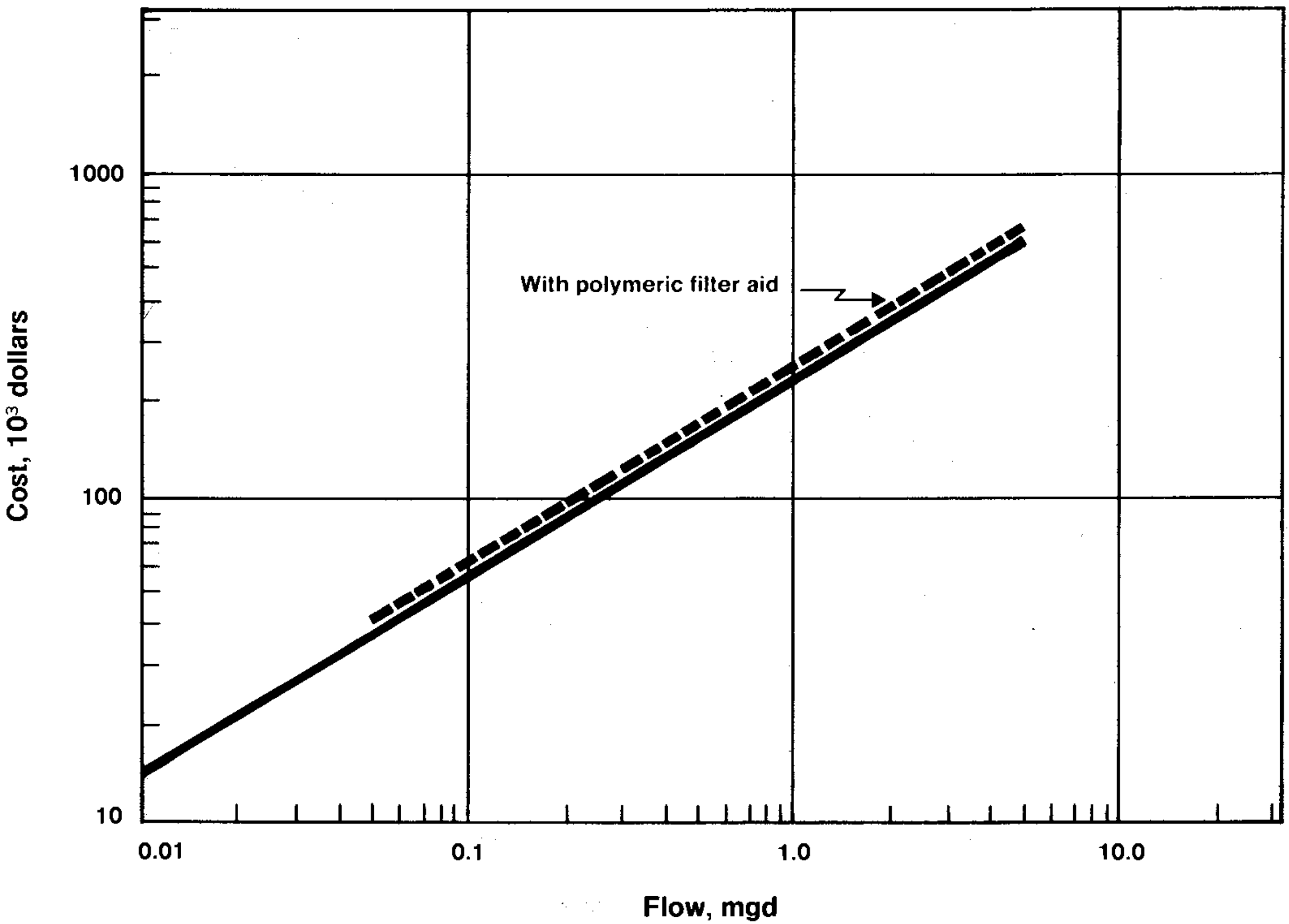


FIGURE VIII-4
ACTIVATED CARBON - INSTALLED COST

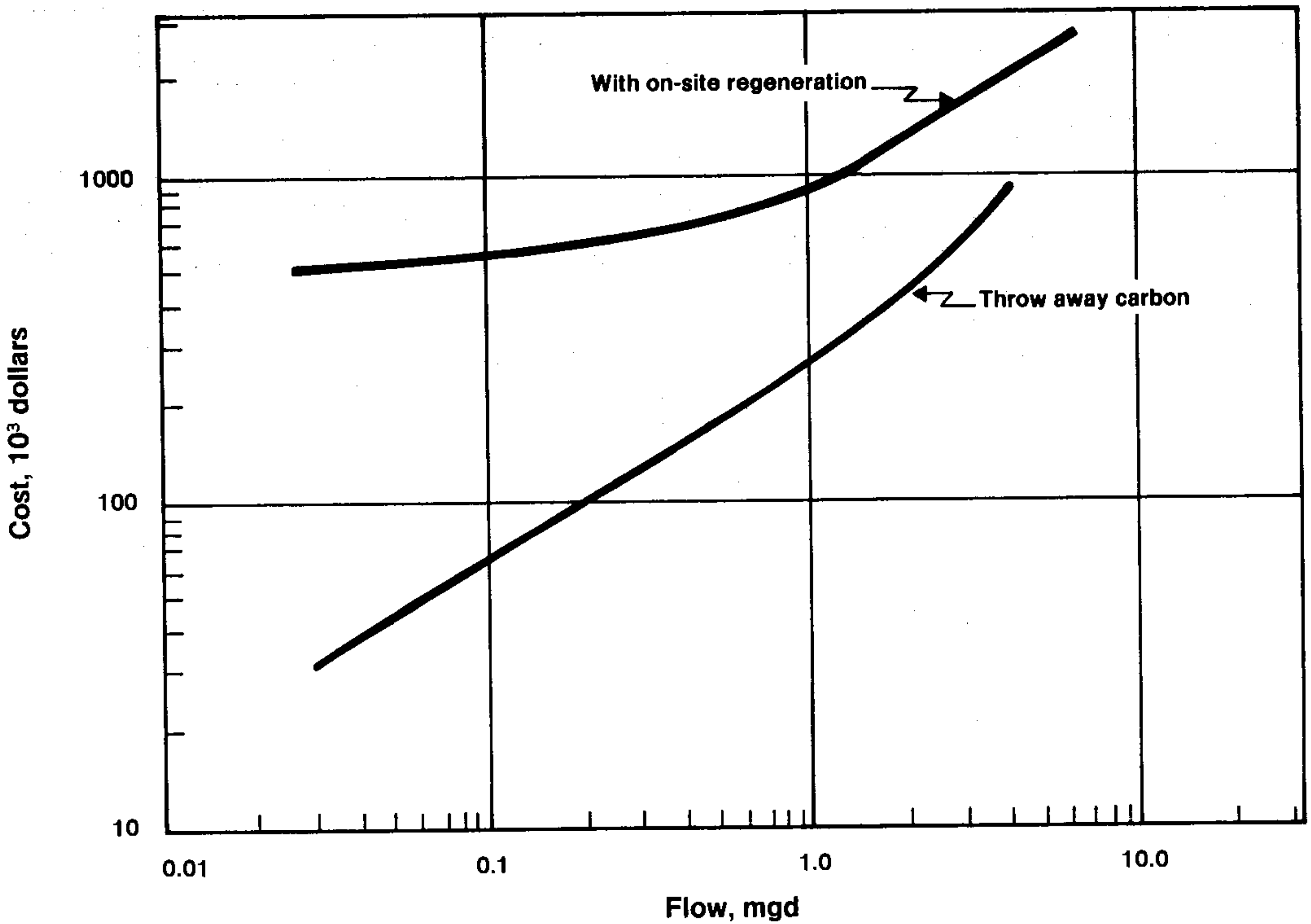


FIGURE VIII-5
OZONATION - INSTALLED COST

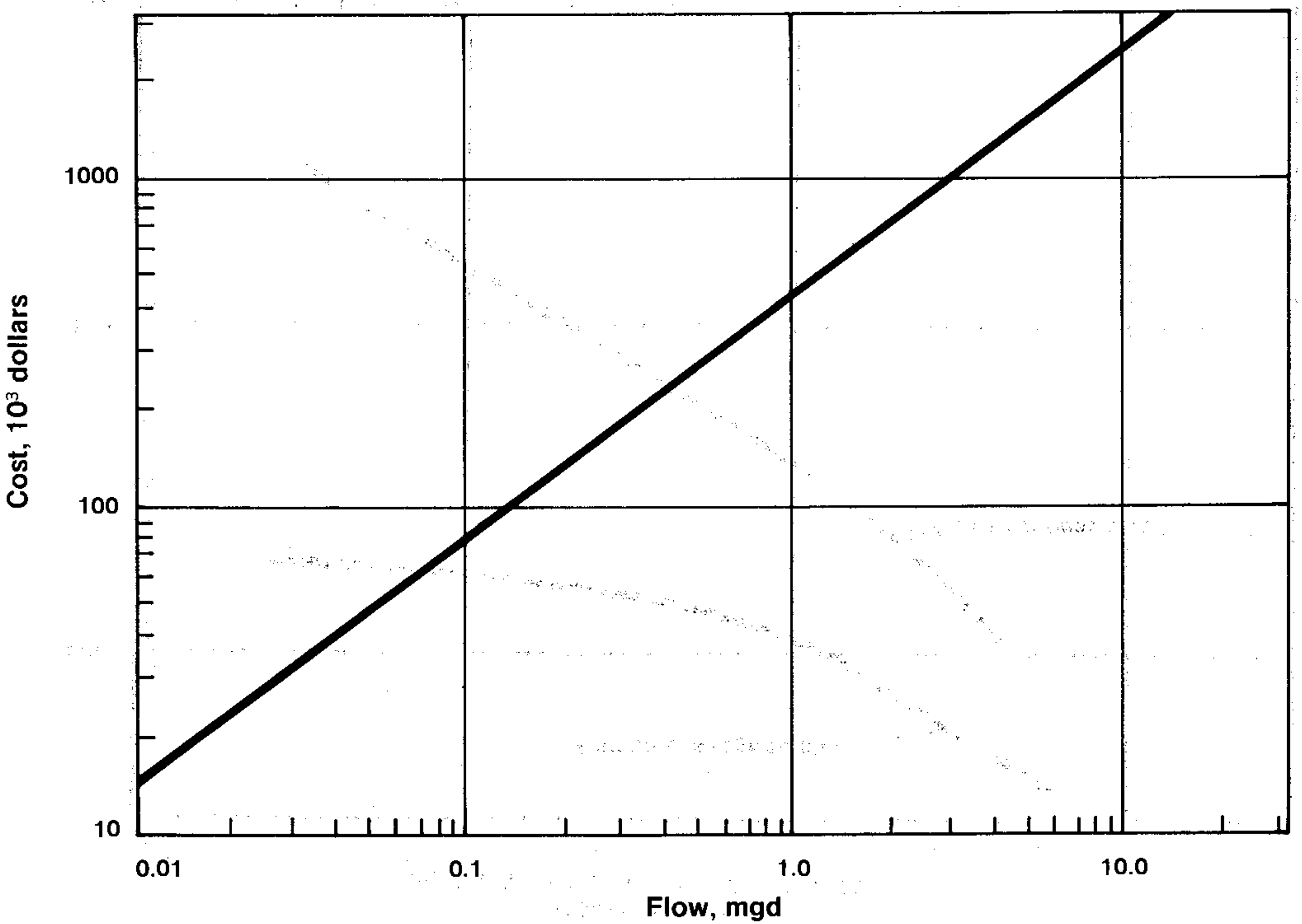


FIGURE VIII-6
VACUUM FILTRATION - INSTALLED COST

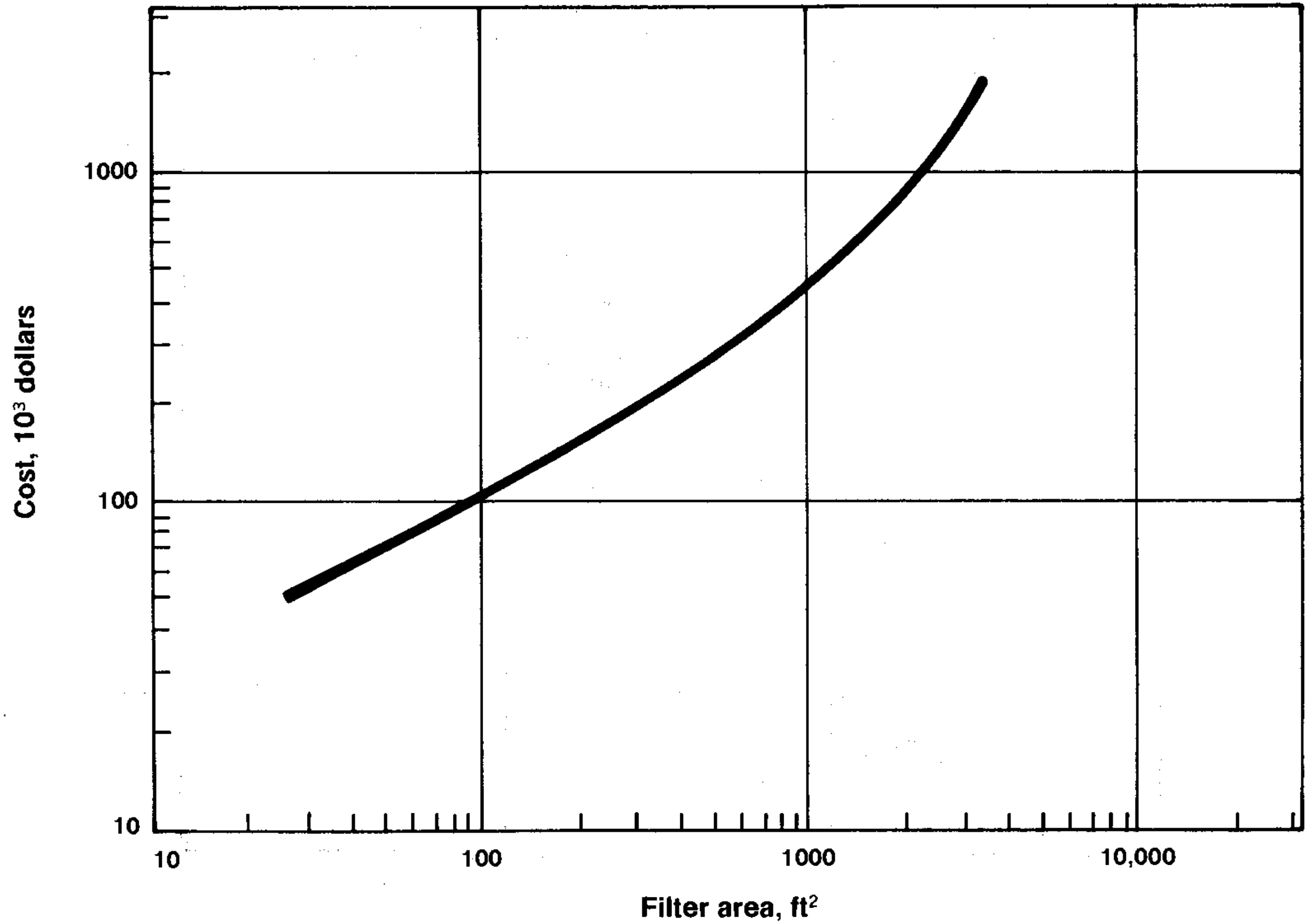


FIGURE VIII-7
ACTIVATED SLUDGE - INSTALLED COST

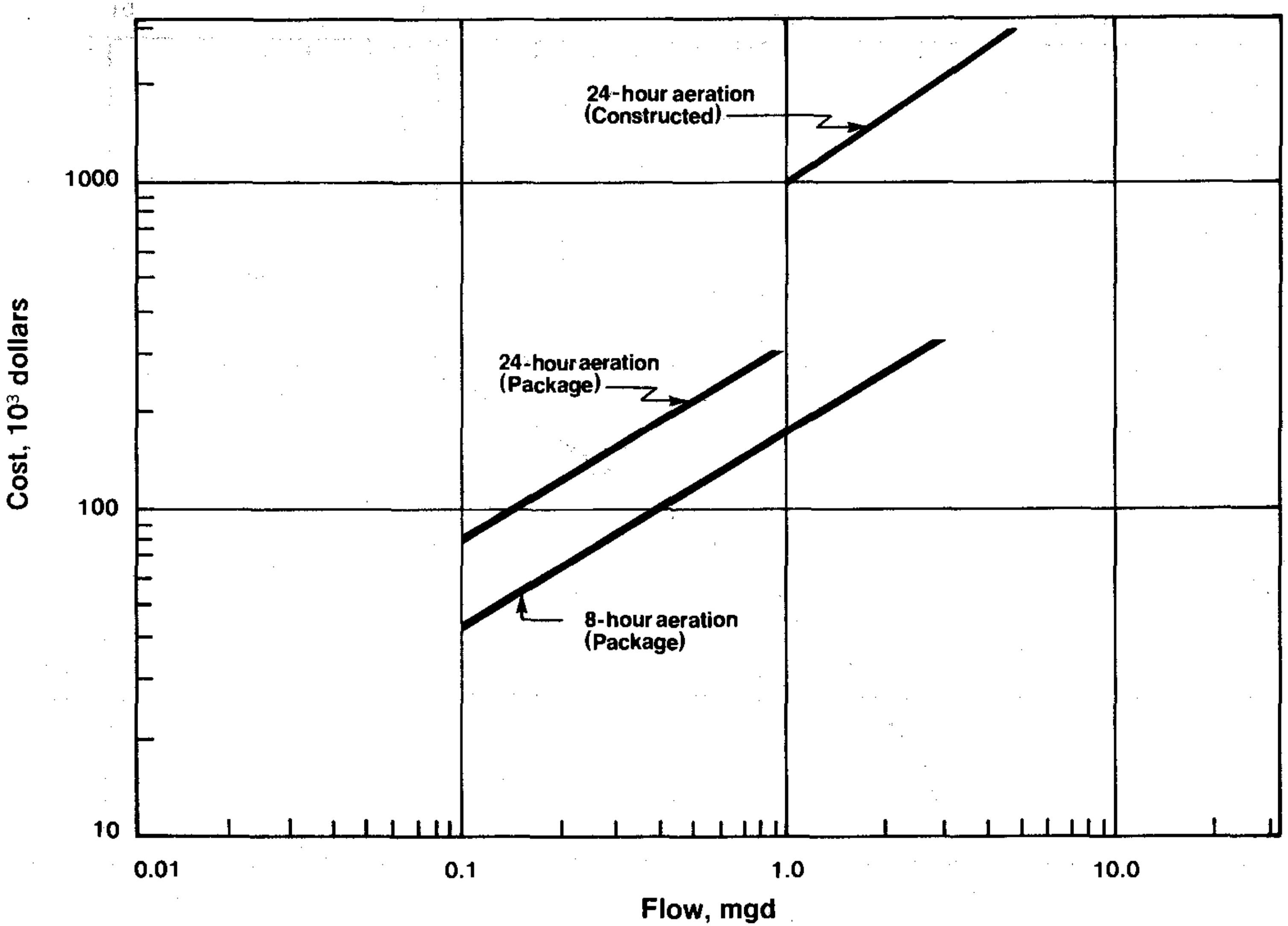


FIGURE VIII-8
HAULING COSTS FOR DEWATERED SLUDGE

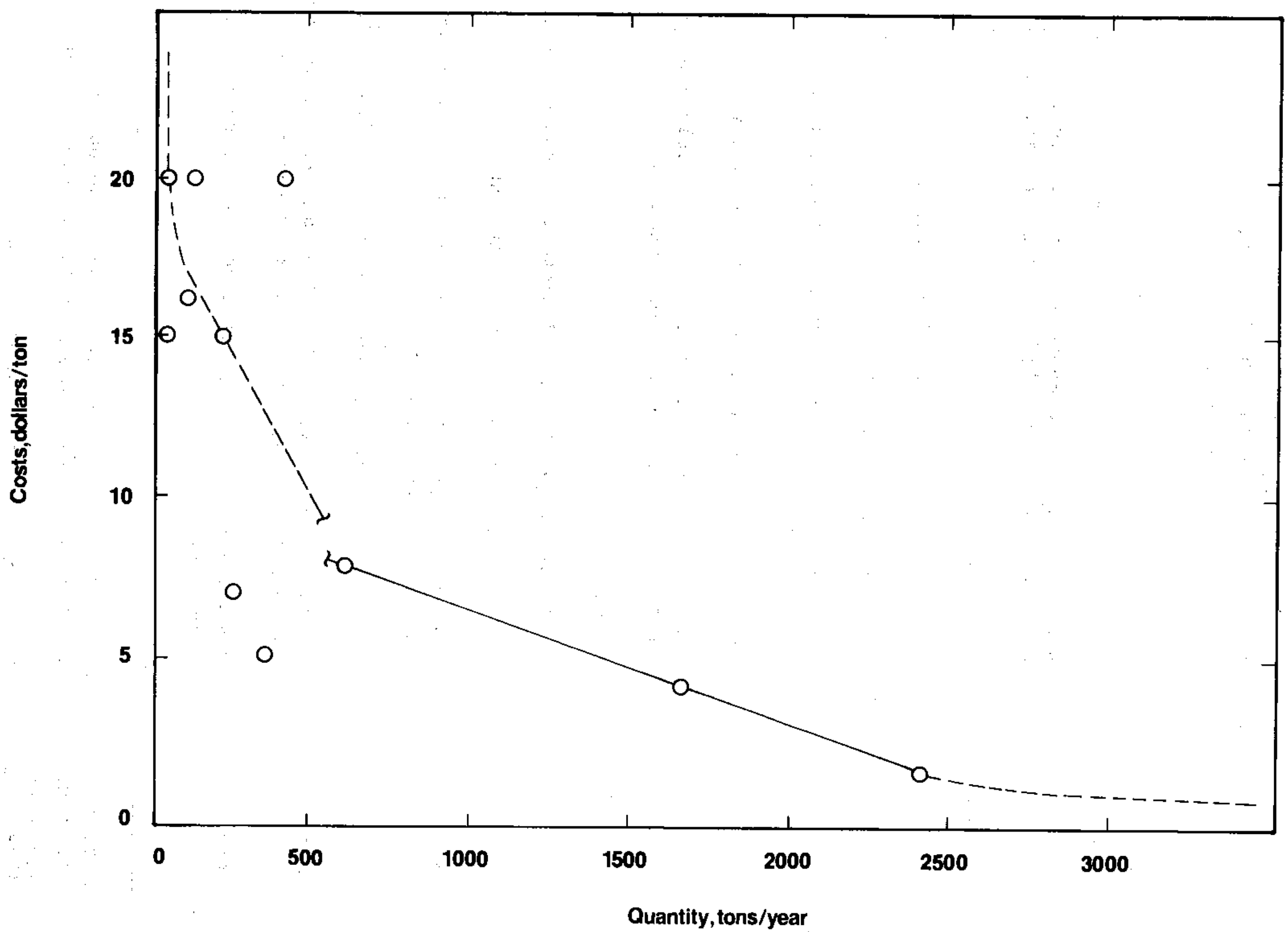


TABLE VIII-1
ALTERNATIVE END-OF-PIPE TREATMENT TECHNOLOGIES
EXISTING SOURCES

Technology	Description
A* Direct	BPT - Screening, extended aeration activated sludge, sedimentation, and solids recycle to aeration basin
Indirect	No treatment
B	Chemical coagulation and sedimentation
C	Multi-media filtration
D	Chemical coagulation, sedimentation, and multi-media filtration
E	Multi-media filtration and granular activated carbon
F	Chemical coagulation, sedimentation, multi-media filtration, and granular activated carbon
G	Ozonation
H	Chemical coagulation, sedimentation, and ozonation
J	Multi-media filtration and ozonation
K	Chemical coagulation, sedimentation, multi-media filtration, and ozonation
M**	Chemical coagulation and dissolved air flotation
N**	Chemical coagulation, dissolved air flotation, multi-media filtration, and granular activated carbon
P**	Chemical coagulation, dissolved air flotation, and ozonation

* Alternative A is considered in place. All other alternatives are added on to A and for indirect dischargers include screening and equalization.
** Alternatives M, N, & P apply to Subcategory 1 only.

TABLE VIII-2
SELECTED MODEL PLANT SIZES
EXISTING SOURCES

	Subcategory	Dis-charge*	Size, mgd 0.05	0.11	0.25	0.6	1.0	1.5	3.0	5.0
1.	Wool Scouring	D	X	(X)	X					
		I	X		(X)					
2.	Wool Finishing	D				X		(X)	X	
		I			X			(X)	X	
4.	Woven Fabric Finishing									
	a. Simple Processing	D		X		(X)		X		
		I	X		(X)		X			
	b. Complex Processing	D				X			(X)	X
		I			X	(X)			X	
	c. Complex Processing Plus Desizing	D				X		(X)		X
		I				X		(X)		X
5.	Knit Fabric Finishing									
	a. Simple Processing	D			X		(X)			X
		I			X	(X)	X			
	b. Complex Processing	D			X	(X)	X			
		I	X			(X)		X		
	c. Hosiery Products	D	X	(X)						
		I	X		(X)					
6.	Carpet Finishing	D			(X)	X		X		
		I		X		(X)		X		
7.	Stock & Yarn Finishing	D			X	(X)	X	X		
		I		X	(X)	X				
8.	Nonwoven Manufacturing	D		(X)	X					
		I		X	X	(X)				
9.	Felted Fabric Processing	D	X	(X)						
		I			(X)	X				

* D refers to direct and I to indirect.
( ) Represents model plant size for which Cost Effectiveness Summaries are included.

costs, including cost of capital, depreciation, operation and maintenance labor, maintenance materials, sludge disposal, energy & power, chemicals, and monitoring, and the benefits in terms of effluent quality are detailed for each alternative. For each subcategory/model plant combination, the corresponding annual and daily production capacity is noted. The summary sheets for the alternative end-of-pipe treatment technologies are provided in Tables VIII-3 through VIII-14.

EXISTING INDIRECT DISCHARGE SOURCES

Selected End-of-Pipe Technologies

The major processes selected for pretreatment for indirect dischargers are the same as for direct-discharge mills, namely; chemical coagulation, dissolved air flotation, filtration, activated carbon adsorption, and ozonation. The treatment goals, i.e., removal of toxic pollutants, are the same for both direct and indirect dischargers, and the available technologies are the same. In addition, screening and equalization are included in the cost estimates for pretreatment facilities. Screening is included because more than half of the direct dischargers provide screening, and it is therefore regarded as a necessary form of preliminary treatment. Equalization is included because the five basic pretreatment processes operate more effectively if fluctuations in loading are minimized. For the direct-discharge mills, the activated sludge aeration tank provides equalization prior to treatment in the advanced units. Neutralization is not included as part of the preliminary treatment sequence because few direct-discharge mills so provide. Where necessary, neutralization would increase investment and annual costs slightly.

As described previously, the current base level of treatment for directdischarge mills is the extended-aeration activated sludge process. The question arises, therefore, as to whether similar biological treatment should be included in the alternative pretreatment technologies. Before evaluating the pros and cons of such inclusion, it is appropriate to consider the positioning of a biological unit in the sequence of processes. For all except Subcategory 1, the best position would be prior to any of the advanced treatment units. It seems doubtful that there would be sufficient organic food material to sustain the microorganisms in the biological treatment unit if it followed chemical coagulation. There would be little benefit in filtering the wastewater prior to biotreatment; the reverse sequence would be more effective. As with chemical coagulation, activated carbon adsorption and/or ozonation prior to biological treatment would be counterproductive in that all three processes are aimed at organic material. In the case of Subcategory 1, treatment by chemical coagulation and/or dissolved air flotation

TABLE VIII-3
MODEL PLANT CONTROL COST SUMMARY - BATEA

SUBCATEGORY: Wool Scouring | CONTROL LEVEL: BATEA | MODEL FLOW: 416 (0.11) cu m/day (mgd)

ANNUAL CAPACITY: 10,700 kkg | DAILY CAPACITY: 35.6 kkg | NUMBER OF MILLS REPRESENTED: 2

	Treatment Alternative			
	A	M	N	P
	Cost, thousands of dollars			
Investment Costs				
Chemical Coagulation				
Equipment	-	11	11	11
Construction	-	43	43	43
Vacuum Filtration				
Equipment	-	19	19	19
Construction	-	34	34	34
Dissolved Air Flotation				
Equipment	-	19	19	19
Construction	-	34	34	34
Multi-Media Filtration				
Equipment	-	-	12	-
Construction	-	-	47	-
Activated Carbon				
Equipment	-	-	32	-
Construction	-	-	33	-
Ozonation				
Equipment	-	-	-	42
Construction	-	-	-	42
Monitoring	-	15	15	15
Engineering	-	20	33	28
Contingencies	-	26	45	39
Total Investment Costs	-	221	377	326

SUBCATEGORY: Wool Scouring CONTROL LEVEL: BATEA MODEL FLOW: 416 (0.11) cu m/day (mgd)

Annual Costs

Capital	-	22	38	33
Depreciation	-	13	22	19
Useful Life (years)	-	15	16	16
O&M Labor	-	41	45	57
Employees (persons)	-	18	19	25
Maintenance	-	8	14	8
Sludge Disposal	-	6	7	5
Energy & Power	-	2	2	11
Chemicals: Polymer	-	-	-	-
Alum	-	22	22	22
Carbon	-	-	91	-
Monitoring	-	27	27	27
Total Annual Costs	-	141	268	182

Effluent Quality

Resulting Mass Loading

BOD5, kg/day	50	17	2	6
COD, kg/day	1080	582	12	25
TSS, kg/day	500	125	4	8
Phenols, g/day	42	42	4	2
Chromium, g/day	17	17	8	17

Resulting Concentration

BOD5, mg/l	120	40	5	15
COD, mg/l	2600	1400	30	60
TSS, mg/l	1200	300	10	20
Phenols, ug/l	100	100	10	5
Chromium, ug/l	40	40	20	40

TABLE VIII-4
MODEL PLANT CONTROL COST SUMMARY - BATEA

SUBCATEGORY: Wool Finishing   CONTROL LEVEL: BATEA   MODEL FLOW: 5,678 (1.5) cu m/day (mgd)

ANNUAL CAPACITY: 6,000 kkg   DAILY CAPACITY: 20 kkg   NUMBER OF MILLS REPRESENTED: 1

	Treatment Alternative						
	A	B	D	F	G	H	K
	Cost, thousands of dollars						
Investment Costs							
Chemical Coagulation							
Equipment	-	50	50	50	-	50	50
Construction	-	200	200	200	-	200	200
Vacuum Filtration							
Equipment	-	20	20	20	-	20	20
Construction	-	38	38	38	-	38	38
Dissolved Air Flotation							
Equipment	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-
Multi-Media Filtration							
Equipment	-	-	52	52	-	-	52
Construction	-	-	208	208	-	-	208
Activated Carbon							
Equipment	-	-	-	540	-	-	-
Construction	-	-	-	540	-	-	-
Ozonation							
Equipment	-	-	-	-	310	310	310
Construction	-	-	-	-	310	310	310
Monitoring	-	15	15	15	15	15	15
Engineering	-	33	50	134	58	81	104
Contingencies	-	48	87	249	95	141	180
Total Investment Costs	-	404	720	2046	788	1165	1487

SUBCATEGORY: Wool Finishing CONTROL LEVEL: BATEA MODEL FLOW: 5,678(1.5) cu m/day (mgd)

Annual Costs							
Capital	-	40	72	205	79	116	149
Depreciation	-	25	45	106	36	60	77
Useful Life (years)	-	15	15	18	20	18	18
O&M Labor	-	67	79	115	33	89	100
Employees (persons)	-	3.0	3.5	5.0	1.5	3.9	4.5
Maintenance	-	42	68	86	6	47	74
Sludge Disposal	-	7	7	7	-	7	7
Energy & Power	-	7	8	39	126	133	134
Chemicals: Polymer	-	-	-	-	-	-	-
Alum	-	30	30	30	-	30	30
Carbon	-	-	-	99	-	-	-
Monitoring	-	27	27	27	27	27	27
Total Annual Costs	-	245	336	719	307	509	598
Effluent Quality							
					Resulting Mass Loading		
BOD5, kg/day	284	142	114	0-28	256	85	28
COD, kg/day	1,363	965	738	256	1,364	512	460
TSS, kg/day	284	199	85	57	568	142	57
Phenols, g/day	455	255	200	57	28	28	28
Chromium, g/day	1,137	1,137	1,137	568	1,137	1,137	1,137
					Resulting Concentration		
BOD5, mg/l	50	25	20	0-5	45	15	5
COD, mg/l	240	170	130	45	240	90	81
TSS, mg/l	50	35	15	10	100	25	10
Phenols, ug/l	80	45	35	10	5	5	5
Chromium, ug/l	200	200	200	100	200	200	200

TABLE VIII-5
MODEL PLANT CONTROL COST SUMMARY - BATEA

SUBCATEGORY: Woven Fabric Finishing-Simple Processing   CONTROL LEVEL: BATEA   MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

ANNUAL CAPACITY: 8,700 kkg   DAILY CAPACITY: 29 kkg   NUMBER OF MILLS REPRESENTED: 8

	Treatment Alternative									
	A	B	C	D	E	F	G	H	J	K
	Cost, thousands of dollars									
Investment Costs										
Chemical Coagulation										
Equipment	-	30	-	30	-	30	-	30	-	30
Construction	-	120	-	120	-	120	-	120	-	120
Vacuum Filtration										
Equipment	-	19	-	19	-	19	-	19	-	19
Construction	-	34	-	34	-	34	-	34	-	34
Dissolved Air Flotation										
Equipment	-	-	-	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-	-	-	-
Multi-Media Filtration										
Equipment	-	-	32	30	32	30	-	-	32	30
Construction	-	-	130	120	130	120	-	-	130	120
Activated Carbon										
Equipment	-	-	-	-	340	340	-	-	-	-
Construction	-	-	-	-	340	340	-	-	-	-
Ozonation										
Equipment	-	-	-	-	-	-	150	150	150	150
Construction	-	-	-	-	-	-	150	150	150	150
Monitoring	-	15	15	15	15	15	15	15	15	15
Engineering	-	24	20	38	74	90	33	48	47	61
Contingencies	-	33	26	55	128	157	47	78	72	100
Total Investment Costs	-	275	223	461	1059	1295	395	644	596	829

SUBCATEGORY: Woven Fabric Finishing-Simple Processing   CONTROL LEVEL: BATEA   MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

Annual Costs

Capital	-	28	22	46	106	130	40	64	60	83
Depreciation	-	17	14	28	52	67	18	33	30	45
Useful Life (years)	-	15	15	15	19	18	20	18	18	17
O&M Labor	-	52	13	58	32	77	25	70	32	77
Employees (persons)	-	2.3	0.6	2.6	1.4	3.4	1.1	3.1	1.4	3.4
Maintenance	-	20	14	34	21	40	2	22	16	36
Sludge Disposal	-	4	1	4	1	4	-	4	1	4
Energy & Power	-	3	0.3	3	13	16	50	54	51	54
Chemicals: Polymer	-	-	2	-	-	-	-	-	2	-
Alum	-	12	-	12	-	12	-	12	-	12
Carbon	-	-	-	-	41	40	-	-	-	-
Monitoring	-	27	27	27	27	27	27	27	27	27
Total Annual Costs	-	163	93	212	293	413	162	286	219	388

Effluent Quality

Resulting Mass Loading										
BOD5, kg/day	34	16	23	16	0-11	0-11	34	11	11	11
COD, kg/day	546	386	431	296	114	80	250	136	205	136
TSS, kg/day	91	57	34	23	23	23	91	23	23	23
Phenols, g/day	68	34	45	34	-	-	-	-	-	-
Chromium, g/day	45	45	45	45	23	23	45	45	45	45

Resulting Concentration										
BOD5, mg/l	15	7	10	7	0-5	0-5	15	5	5	5
COD, mg/l	240	170	190	130	50	35	110	60	90	60
TSS, mg/l	40	25	15	10	10	10	40	10	10	10
Phenols, ug/l	30	15	20	15	-	-	-	-	-	-
Chromium, ug/l	20	20	20	20	10	10	20	20	20	20

TABLE VIII-6
MODEL PLANT CONTROL COST SUMMARY - BATEA

SUBCATEGORY: Woven Fabric Finishing-Complex Processing   CONTROL LEVEL: BATEA   MODEL FLOW: 11,355 (3.0) cu m/day (mgd)

ANNUAL CAPACITY: 39,000 kg   DAILY CAPACITY: 130 kkg   NUMBER OF MILLS REPRESENTED: 5

	Treatment Alternative									
	A	B	C	D	E	F	G	H	J	K
	Cost, thousands of dollars									
Investment Costs										
Chemical Coagulation										
Equipment	-	76	-	76	-	76	-	76	-	76
Construction	-	304	-	304	-	304	-	304	-	304
Vacuum Filtration										
Equipment	-	23	-	23	-	23	-	23	-	23
Construction	-	44	-	44	-	44	-	44	-	44
Dissolved Air Flotation										
Equipment	-	-	-	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-	-	-	-
Multi-Media Filtration										
Equipment	-	-	87	82	87	82	-	-	87	82
Construction	-	-	350	328	350	328	-	-	350	328
Activated Carbon										
Equipment	-	-	-	-	800	800	-	-	-	-
Construction	-	-	-	-	800	800	-	-	-	-
Ozonation										
Equipment	-	-	-	-	-	-	525	525	525	525
Construction	-	-	-	-	-	-	525	525	525	525
Monitoring	-	15	15	15	15	15	15	15	15	15
Engineering	-	45	44	75	165	185	92	122	121	155
Contingencies	-	69	68	131	308	371	160	227	225	288
Total Investment Costs	-	576	564	1078	2525	3028	1317	1861	1848	2365

SUBCATEGORY: Woven Fabric Finishing - Complex Processing   CONTROL LEVEL: BATEA   MODEL FLOW: 11,355 (3.0) cu m/day (mgd)

Annual Costs

Capital	-	58	56	108	252	303	132	186	185	236
Depreciation	-	35	35	67	139	158	61	92	91	123
Useful Life (years)	-	15	15	15	17	18	20	19	19	18
O&M Labor	-	88	34	105	95	166	41	111	58	129
Employees (persons)	-	3.9	1.5	4.6	4.2	7.4	1.8	5.0	2.6	5.7
Maintenance	-	77	43	120	76	153	11	88	54	131
Sludge Disposal	-	7	6	7	6	7	-	7	6	7
Energy & Power	-	14	2	16	61	75	252	266	254	267
Chemicals: Polymer	-	-	8	-	-	-	-	-	8	-
Alum	-	60	-	60	-	60	-	60	-	60
Carbon	-	-	-	-	206	198	-	-	-	-
Monitoring	-	27	27	27	27	27	27	27	27	27
Total Annual Costs	-	366	211	510	862	1147	524	837	683	980

Effluent Quality

Resulting Mass Loading

BOD5, kg/day	284	114	227	114	0-57	0-57	284	114	57	57
COD, kg/day	2842	2044	2271	1590	568	398	1251	739	966	682
TSS, kg/day	568	397	227	170	114	114	568	170	114	114
Phenols, g/day	795	454	568	341	114	114	57	57	57	57
Chromium, g/day	341	341	341	341	170	170	341	341	341	341

Resulting Concentration

BOD5, mg/l	25	10	20	10	0-5	0-5	25	10	5	5
COD, mg/l	250	180	200	140	50	35	110	65	85	60
TSS, mg/l	50	35	20	15	10	10	50	15	10	10
Phenols, ug/l	70	40	50	30	10	10	5	5	5	5
Chromium, ug/l	30	30	30	30	15	15	30	30	30	30

TABLE VIII-7
MODEL PLANT CONTROL COST SUMMARY - BATEA

SUBCATEGORY: Woven Fabric Finishing - Complex Processing Plus Desizing CONTROL LEVEL: BATEA MODEL FLOW: 5,678 (1.5) cu m/day (mgd)

ANNUAL CAPACITY: 15,000 kkg DAILY CAPACITY: 50 kkg NUMBER OF MILLS REPRESENTED: 8

	Treatment Alternative									
	A	B	C	D	E	F	G	H	J	K
	Cost, thousands of dollars									
Investment Costs										
Chemical Coagulation										
Equipment	-	50	-	50	-	50	-	50	-	50
Construction	-	200	-	200	-	200	-	200	-	200
Vacuum Filtration										
Equipment	-	19	-	19	-	19	-	19	-	19
Construction	-	34	-	34	-	34	-	34	-	34
Dissolved Air Flotation										
Equipment	-	-	-	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-	-	-	-
Multi-Media Filtration										
Equipment	-	-	56	52	56	52	-	-	56	52
Construction	-	-	223	208	223	208	-	-	223	208
Activated Carbon										
Equipment	-	-	-	-	540	540	-	-	-	-
Construction	-	-	-	-	540	540	-	-	-	-
Ozonation										
Equipment	-	-	-	-	-	-	310	310	310	310
Construction	-	-	-	-	-	-	310	310	310	310
Monitoring	-	15	15	15	15	15	15	15	15	15
Engineering	-	33	32	53	111	133	58	81	79	103
Contingencies	-	48	44	87	206	249	95	141	137	180
Total Investment Costs	-	399	370	718	1691	2040	788	1160	1130	1481

SUBCATEGORY: Woven Fabric Finishing - Complex Processing Plus Desizing CONTROL LEVEL: BATEA MODEL FLOW: 5,678 (1.5) cu m/day (mgd)

Annual Costs										
Capital	-	40	37	72	169	204	79	116	113	148
Depreciation	-	24	23	44	93	106	37	60	55	76
Useful Life (years)	-	15	15	15	17	18	20	18	19	18
O&M Labor	-	67	23	79	59	115	33	89	45	100
Employees (persons)	-	3.0	1.0	3.5	2.6	5.1	1.5	3.9	2.0	4.5
Maintenance	-	42	27	68	44	86	6	47	33	74
Sludge Disposal	-	6	4	6	3	6	-	6	3	6
Energy & Power	-	7	1	8	32	39	126	133	127	134
Chemicals: Polymer	-	-	4	-	-	-	-	-	4	-
Alum	-	30	-	30	-	30	-	30	-	30
Carbon	-	-	-	-	103	99	-	-	-	-
Monitoring	-	27	27	27	27	27	27	27	27	27
Total Annual Costs	-	243	146	334	530	712	308	508	407	595
Effluent Quality										
					Resulting Mass Loading					
BOD5, kg/day	142	57	114	57	0-28	0-28	142	57	28	28
COD, kg/day	1421	1022	1136	795	284	199	625	370	483	341
TSS, kg/day	284	199	114	85	57	57	284	85	57	57
Phenols, g/day	284	170	199	142	28	28	-	-	-	-
Chromium, g/day	170	170	170	170	85	85	170	170	170	170
					Resulting Concentration					
BOD5, mg/l	25	10	20	10	0-5	0-5	25	10	5	5
COD, mg/l	250	180	200	140	50	35	110	65	85	60
TSS, mg/l	50	35	20	15	10	10	50	15	10	10
Phenols, ug/l	50	30	35	25	5	5	-	-	-	-
Chromium, ug/l	30	30	30	30	15	15	30	30	30	30

TABLE VIII-8
MODEL PLANT CONTROL COST SUMMARY - BATEA

SUBCATEGORY: Knit Fabric Finishing - Simple Processing CONTROL LEVEL: BATEA MODEL FLOW: 3,785 (1.0) cu m/day (mgd)

ANNUAL CAPACITY: 9,300 kkg DAILY CAPACITY: 31 kkg NUMBER OF MILLS REPRESENTED: 13

	Treatment Alternative									
	A	B	C	D	E	F	G	H	J	K
	Cost, thousands of dollars									
Investment Costs										
Chemical Coagulation										
Equipment	-	40	-	40	-	40	-	40	-	40
Construction	-	160	-	160	-	160	-	160	-	160
Vacuum Filtration										
Equipment	-	19	-	19	-	19	-	19	-	19
Construction	-	34	-	34	-	34	-	34	-	34
Dissolved Air Flotation										
Equipment	-	-	-	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-	-	-	-
Multi-Media Filtration										
Equipment	-	-	43	40	43	40	-	-	43	40
Construction	-	-	174	160	174	160	-	-	174	160
Activated Carbon										
Equipment	-	-	-	-	415	415	-	-	-	-
Construction	-	-	-	-	415	415	-	-	-	-
Ozonation										
Equipment	-	-	-	-	-	-	230	230	230	230
Construction	-	-	-	-	-	-	230	230	230	230
Monitoring	-	15	15	15	15	15	15	15	15	15
Engineering	-	29	25	46	92	112	46	67	64	80
Contingencies	-	40	35	70	159	195	71	109	104	139
Total Investment Costs	-	337	292	584	1313	1605	592	904	860	1147

SUBCATEGORY: Knit Fabric Finishing - Simple Processing CONTROL LEVEL: BATEA MODEL FLOW: 3,785 (1.0) cu m/day (mgd)

Annual Costs										
Capital	-	34	29	58	131	160	59	90	86	115
Depreciation	-	20	18	36	68	83	27	46	44	59
Useful Life (years)	-	15	15	15	18	18	20	18	18	18
O&M Labor	-	59	18	68	46	96	29	79	38	88
Employees (persons)	-	2.6	0.8	3.0	2.0	4.3	1.3	3.5	1.7	3.9
Maintenance	-	28	20	48	31	60	4	32	24	52
Sludge Disposal	-	5	2	4	2	5	-	5	2	5
Energy & Power	-	5	0.6	5	21	26	84	89	85	89
Chemicals: Polymer	-	-	2	-	-	-	-	-	3	-
Alum	-	20	-	20	-	20	-	20	-	20
Carbon	-	-	-	-	69	66	-	-	-	-
Monitoring	-	27	27	27	27	27	27	27	27	27
Total Annual Costs	-	198	117	266	395	543	230	388	309	455
Effluent Quality										
					Resulting Mass Loading					
BOD5, kg/day	57	19	38	19	0-19	0-19	57	19	19	19
COD, kg/day	1023	719	833	568	227	152	455	265	379	265
TSS, kg/day	133	95	57	38	38	38	133	38	38	38
Phenols, g/day	227	132	151	95	19	19	19	19	19	19
Chromium, g/day	227	227	227	227	114	114	227	227	227	227
					Resulting Concentration					
BOD5, mg/l	15	5	10	5	0-5	0-5	15	5	5	5
COD, mg/l	270	190	220	150	60	40	120	70	100	70
TSS, mg/l	35	25	15	10	10	10	35	10	10	10
Phenols, ug/l	60	35	40	25	5	5	5	5	5	5
Chromium, ug/l	60	60	60	60	30	30	60	60	60	60

TABLE VIII-9

MODEL PLANT CONTROL COST SUMMARY - BATEA

SUBCATEGORY: Knit Fabric Finishing - Complex Processing   CONTROL LEVEL: BATEA   MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

ANNUAL CAPACITY: 5,600 kkg   DAILY CAPACITY: 18.6 kkg   NUMBER OF MILLS REPRESENTED: 4

	Treatment Alternative									
	A	B	C	D	E	F	G	H	J	K
	Cost, thousands of dollars									
Investment Costs										
Chemical Coagulation										
Equipment	-	30	-	30	-	30	-	30	-	30
Construction	-	120	-	120	-	120	-	120	-	120
Vacuum Filtration										
Equipment	-	19	-	19	-	19	-	19	-	19
Construction	-	34	-	34	-	34	-	34	-	34
Dissolved Air Flotation										
Equipment	-	-	-	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-	-	-	-
Multi-Media Filtration										
Equipment	-	-	32	30	32	30	-	-	32	30
Construction	-	-	130	120	130	120	-	-	130	120
Activated Carbon										
Equipment	-	-	-	-	340	340	-	-	-	-
Construction	-	-	-	-	340	340	-	-	-	-
Ozonation										
Equipment	-	-	-	-	-	-	150	150	150	150
Construction	-	-	-	-	-	-	150	150	150	150
Monitoring	-	15	15	15	15	15	15	15	15	15
Engineering	-	25	20	38	74	90	33	48	47	61
Contingencies	-	33	26	55	128	157	47	78	71	100
Total Investment Costs	-	276	223	461	1059	1295	395	644	595	829

SUBCATEGORY: Knit Fabric Finishing - Complex Processing   CONTROL LEVEL: BATEA   MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

Annual Costs										
Capital	-	28	22	46	106	130	40	64	60	83
Depreciation	-	17	14	28	52	67	18	33	30	45
Useful Life (years)	-	15	15	15	19	18	20	18	18	17
O&M Labor	-	52	13	58	32	77	25	70	32	77
Employees (persons)	-	2.3	0.6	2.6	1.4	3.4	1.1	3.1	1.4	3.4
Maintenance	-	20	14	34	21	40	2	22	16	36
Sludge Disposal	-	4	2	4	2	4	-	4	2	4
Energy & Power	-	3	0.3	3	13	16	50	54	51	54
Chemicals: Polymer	-	-	2	-	-	-	-	-	2	-
Alum	-	12	-	12	-	12	-	12	-	12
Carbon	-	-	-	-	40	40	-	-	-	-
Monitoring	-	27	27	27	27	27	27	27	27	27
Total Annual Costs	-	163	94	212	293	413	162	286	220	338
Effluent Quality										
Resulting Mass Loading										
BOD5, kg/day	45	23	34	23	0-11	0-11	45	11	11	11
COD, kg/day	637	454	500	341	125	79	296	159	228	148
TSS, kg/day	125	79	45	34	23	23	125	34	23	23
Phenols, g/day	136	79	91	68	11	11	11	11	11	11
Chromium, g/day	57	57	57	57	23	23	57	57	57	57
Resulting Concentration										
BOD5, mg/l	20	10	15	10	0-5	0-5	20	5	5	5
COD, mg/l	280	200	220	150	55	35	130	70	100	65
TSS, mg/l	55	35	20	15	10	10	55	15	10	10
Phenols, ug/l	60	35	40	30	5	5	5	5	5	5
Chromium, ug/l	25	25	25	25	10	10	25	25	25	25

TABLE VIII-10
MODEL PLANT CONTROL COST SUMMARY - BATEA

SUBCATEGORY: Knit Fabric Finishing - Hosiery Products   CONTROL LEVEL: BATEA   MODEL FLOW: 416 (0.11) cu m/day (mgd)

ANNUAL CAPACITY: 1,800 kkg   DAILY CAPACITY: 6 kkg   NUMBER OF MILLS REPRESENTED: 1

	Treatment Alternative						
	A	B	D	F	G	H	K
	Cost, thousands of dollars						
Investment Costs							
Preliminary Treatment							
Equipment	5	-	-	-	-	-	-
Construction	21	-	-	-	-	-	-
Activated Sludge							
Equipment	18	-	-	-	-	-	-
Construction	72	-	-	-	-	-	-
Chemical Coagulation							
Equipment	-	11	11	11	-	11	11
Construction	-	43	43	43	-	43	43
Vacuum Filtration							
Equipment	19	19	19	19	-	19	19
Construction	34	34	34	34	-	34	34
Dissolved Air Flotation							
Equipment	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-
Multi-Media Filtration							
Equipment	-	-	12	12	-	-	12
Construction	-	-	47	47	-	-	47
Activated Carbon							
Equipment	-	-	-	32	-	-	-
Construction	-	-	-	33	-	-	-
Ozonation							
Equipment	-	-	-	-	42	42	42
Construction	-	-	-	-	42	42	42
Monitoring	15	15	15	15	15	15	15
Engineering	21	15	21	27	13	24	29
Contingencies	28	18	27	37	15	31	40
Total Investment Costs	233	155	229	310	127	261	334

SUBCATEGORY: Knit Fabric Finishing - Hosiery Products   CONTROL LEVEL: BATEA   MODEL FLOW: 416 (0.11) cu m/day (mgd)

Annual Costs							
Capital	23	16	23	31	13	26	33
Depreciation	14	9	14	18	6	14	18
Useful Life (years)	15	15	15	16	20	17	17
O&M Labor	23	38	40	41	15	53	54
Employees (persons)	1.0	1.7	1.8	1.8	0.7	2.3	2.4
Maintenance	7	6	10	12	0.4	6	11
Sludge Disposal	3	1	1	4	-	1	1
Energy & Power	7	1	1	1	9	10	10
Chemicals: Polymer	-	-	-	-	-	-	-
Alum	-	2	2	2	-	2	2
Carbon	-	-	-	91	-	-	-
Monitoring	27	27	27	27	27	27	27
Total Annual Costs	104	100	118	227	70	139	156
Effluent Quality							
				Resulting Mass Loading			
BOD5, kg/day	29	12	12	0-2	27	8	2
COD , kg/day	238	166	129	21	108	42	38
TSS, kg/day	54	35	15	4	54	12	4
Phenols, g/day	25	15	12	2	-	-	-
Chromium, g/day	12	12	12	6	12	12	12
				Resulting Concentration			
BOD5, mg/l	70	30	30	0-5	65	20	5
COD, mg/l	570	400	310	50	260	100	90
TSS, mg/l	130	85	35	10	130	30	10
Phenols, ug/l	60	35	30	5	-	-	-
Chromium, ug/l	30	30	30	15	30	30	30

TABLE VIII-11
MODEL PLANT CONTROL COST SUMMARY - BATEA

SUBCATEGORY: Carpet Finishing | CONTROL LEVEL: BATEA | MODEL FLOW: 946 (0.25) cu m/day (mgd)

ANNUAL CAPACITY: 6,100 kkg | DAILY CAPACITY: 20 kkg | NUMBER OF MILLS REPRESENTED: 10

	Treatment Alternative									
	A	B	C	D	E	F	G	H	J	K
	Cost, thousands of dollars									
Investment Costs										
Chemical Coagulation										
Equipment	-	18	-	18	-	18	-	18	-	18
Construction	-	70	-	70	-	70	-	70	-	70
Vacuum Filtration										
Equipment	-	19	-	19	-	19	-	19	-	19
Construction	-	34	-	34	-	34	-	34	-	34
Dissolved Air Flotation										
Equipment	-	-	-	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-	-	-	-
Multi-Media Filtration										
Equipment	-	-	21	19	21	19	-	-	21	19
Construction	-	-	82	77	82	77	-	-	82	77
Activated Carbon										
Equipment	-	-	-	-	300	300	-	-	-	-
Construction	-	-	-	-	300	300	-	-	-	-
Ozonation										
Equipment	-	-	-	-	-	-	80	80	80	80
Construction	-	-	-	-	-	-	80	80	80	80
Monitoring	-	15	15	15	15	15	15	15	15	15
Engineering	-	19	15	28	66	73	12	34	30	40
Contingencies	-	23	18	38	108	128	26	47	42	62
Total Investment Costs	-	198	151	318	892	1053	213	397	350	514

SUBCATEGORY: Carpet Finishing CONTROL LEVEL: BATEA MODEL FLOW: 946 (0.25) cu m/day (mgd)

Annual Costs										
Capital	-	20	15	32	89	105	21	40	35	51
Depreciation	-	12	9	19	43	52	10	20	18	28
Useful Life (years)	-	15	15	15	19	19	20	18	18	17
O&M Labor	-	41	5	45	16	55	18	58	22	61
Employees (persons)	-	1.8	0.2	2.0	0.7	2.4	0.8	2.6	1.0	2.7
Maintenance	-	10	8	18	11	21	1	11	9	19
Sludge Disposal	-	2	1	2	1	2	-	2	1	2
Energy & Power	-	2	0.2	2	5	7	21	23	21	23
Chemicals: Polymer	-	-	1	-	-	-	-	-	1	-
Alum	-	5	-	5	-	5	-	5	-	5
Carbon	-	-	-	-	17	16	-	-	-	-
Monitoring	-	27	27	27	27	27	27	27	27	27
Total Annual Costs	-	119	66	150	209	290	98	186	134	216
Effluent Quality										
Resulting Mass Loading										
BOD5, kg/day	33	14	24	14	0-5	0-5	33	9	5	5
COD , kg/day	275	189	218	151	52	38	123	66	95	66
TSS, kg/day	57	38	19	14	9	9	57	14	9	9
Phenols, g/day	95	52	66	43	9	9	5	5	5	5
Chromium, g/day	24	24	24	24	9	9	24	24	24	24
Resulting Concentration										
BOD5, mg/l	35	15	25	15	0-5	0-5	35	10	5	5
COD, mg/l	290	200	230	160	55	40	130	70	100	70
TSS, mg/l	60	40	20	15	10	10	60	15	10	10
Phenols, ug/l	100	55	70	45	10	10	5	5	5	5
Chromium, ug/l	25	25	25	25	10	10	25	25	25	25

TABLE VIII-12
MODEL PLANT CONTROL COST SUMMARY - BATEA

SUBCATEGORY: Stock & Yarn Finishing CONTROL LEVEL: BATEA MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

ANNUAL CAPACITY: 6,800 kkg DAILY CAPACITY: 23 kkg NUMBER OF MILLS REPRESENTED: 6

	Treatment Alternative									
	A	B	C	D	E	F	G	H	J	K
	Cost, thousands of dollars									
Investment Costs										
Chemical Coagulation										
Equipment	-	30	-	30	-	30	-	30	-	30
Construction	-	120	-	120	-	120	-	120	-	120
Vacuum Filtration										
Equipment	-	19	-	19	-	19	-	19	-	19
Construction	-	34	-	34	-	34	-	34	-	34
Dissolved Air Flotation										
Equipment	-	-	-	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-	-	-	-
Multi-Media Filtration										
Equipment	-	-	32	30	32	30	-	-	32	30
Construction	-	-	130	120	130	120	-	-	130	120
Activated Carbon										
Equipment	-	-	-	-	340	340	-	-	-	-
Construction	-	-	-	-	340	340	-	-	-	-
Ozonation										
Equipment	-	-	-	-	-	-	150	150	150	150
Construction	-	-	-	-	-	-	150	150	150	150
Monitoring	-	15	15	15	15	15	15	15	15	15
Engineering	-	24	20	38	74	90	33	48	47	61
Contingencies	-	33	26	55	128	157	47	78	72	100
Total Investment Costs	-	275	223	461	1059	1295	395	644	596	829

SUBCATEGORY: Stock & Yarn Finishing CONTROL LEVEL: BATEA MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

Annual Costs

Capital	-	28	22	46	106	130	40	64	60	83
Depreciation	-	17	14	28	52	67	18	33	30	45
Useful Life (years)	-	15	15	15	19	18	20	18	18	17
O&M Labor	-	52	13	58	32	77	25	70	32	77
Employees (persons)	-	2.3	0.6	2.6	1.4	3.4	1.1	3.1	1.4	3.4
Maintenance	-	20	14	34	21	40	2	22	16	36
Sludge Disposal	-	4	1	4	1	4	-	4	1	4
Energy & Power	-	3	0.3	3	13	16	50	54	51	54
Chemicals: Polymer	-	-	2	-	-	-	-	-	2	-
Alum	-	12	-	12	-	12	-	12	-	12
Carbon	-	-	-	-	41	40	-	-	-	-
Monitoring	-	27	27	27	27	27	27	27	27	27
Total Annual Costs	-	163	93	212	293	413	162	286	219	338

Effluent Quality

	Resulting Mass Loading									
BOD5, kg/day	23	11	23	11	0-11	0-11	23	11	11	11
COD, kg/day	318	227	250	182	68	45	148	91	125	80
TSS, kg/day	57	34	23	11	23	23	57	23	23	23
Phenols, g/day	136	79	91	68	11	11	11	11	11	11
Chromium, g/day	91	91	91	91	45	45	91	91	91	91
	Resulting Concentration									
BOD5, mg/l	10	5	10	5	0-5	0-5	10	5	5	5
COD, mg/l	140	100	110	80	30	20	65	40	55	35
TSS, mg/l	25	15	10	5	10	10	25	10	10	10
Phenols, ug/l	60	35	40	30	5	5	5	5	5	5
Chromium, ug/l	40	40	40	40	20	20	40	40	40	40

TABLE VIII-13

MODEL PLANT CONTROL COST SUMMARY - BATEA

SUBCATEGORY: Nonwoven Manufacturing   CONTROL LEVEL: BATEA   MODEL FLOW: 416 (0.11) cu m/day (mgd)

ANNUAL CAPACITY: 3,120 kkg   DAILY CAPACITY: 10.4 kkg   NUMBER OF MILLS REPRESENTED: 5

	Treatment Alternative									
	A	B	C	D	E	F	G	H	J	K
	Cost, thousands of dollars									
Investment Costs										
Preliminary Treatment										
Equipment	5	-	-	-	-	-	-	-	-	-
Construction	21	-	-	-	-	-	-	-	-	-
Activated Sludge										
Equipment	18	-	-	-	-	-	-	-	-	-
Construction	72	-	-	-	-	-	-	-	-	-
Chemical Coagulation										
Equipment	-	11	-	11	-	11	-	11	-	11
Construction	-	43	-	43	-	43	-	43	-	43
Vacuum Filtration										
Equipment	19	19	-	19	-	19	-	19	-	19
Construction	34	34	-	34	-	34	-	34	-	34
Dissolved Air Flotation										
Equipment	-	-	-	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-	-	-	-
Multi-Media Filtration										
Equipment	-	-	13	12	13	12	-	-	13	12
Construction	-	-	53	47	50	47	-	-	50	47
Activated Carbon										
Equipment	-	-	-	-	13	32	-	-	-	-
Construction	-	-	-	-	52	33	-	-	-	-
Ozonation										
Equipment	-	-	-	-	-	-	42	42	42	42
Construction	-	-	-	-	-	-	42	42	42	42
Monitoring	15	15	15	15	15	15	15	15	15	15
Engineering	21	15	10	21	17	27	13	24	20	29
Contingencies	28	18	12	27	21	37	15	31	24	40
Total Investment Costs	233	155	100	229	181	310	127	261	206	334

SUBCATEGORY: Nonwoven Manufacturing   CONTROL LEVEL: BATEA   MODEL FLOW: 416 (0.11) cu m/day (mgd)

Annual Costs										
Capital	23	16	10	23	18	31	13	26	21	33
Depreciation	14	9	6	14	9	18	6	14	10	18
Useful Life (years)	15	15	15	15	18	16	20	17	18	17
O&M Labor	23	38	3	40	2	41	15	53	17	54
Employees (persons)	1.0	1.7	0.1	1.8	0.1	1.8	0.7	2.3	0.7	3.1
Maintenance	7	6	4	10	6	12	0.4	6	5	11
Sludge Disposal	3	1	0.5	1	0.5	4	-	1	0.5	1
Energy & Power	7	1	0.07	1	1	1	9	10	9	10
Chemicals: Polymer	-	-	0.3	-	-	-	-	-	0.3	-
Alum	-	2	-	2	-	2	-	2	-	2
Carbon	-	-	-	-	3	91	-	-	-	-
Monitoring	27	27	27	27	27	27	27	27	27	27
Total Annual Costs	104	100	51	118	68	227	70	139	90	156
Effluent Quality										
Resulting Mass Loading										
BOD5, kg/day	15	6	10	6	2	2	15	4	8	4
COD , kg/day	235	166	187	129	50	23	106	44	89	42
TSS, kg/day	31	21	10	8	4	4	31	8	4	4
Phenols, g/day	8	8	8	8	0-2	0-2	0	0	0	0
Chromium, g/day	2	2	2	2	0-2	0-2	2	2	2	2
Resulting Concentration										
BOD5, mg/l	35	15	25	15	5	5	35	10	10	10
COD, mg/l	565	400	450	310	120	55	255	105	215	100
TSS, mg/l	75	50	25	20	10	10	75	20	10	10
Phenols, ug/l	20	20	20	20	0-5	0-5	0	0	0	0
Chromium, ug/l	5	5	5	5	0-5	0-5	5	5	5	5

TABLE VIII-14
MODEL PLANT CONTROL COST SUMMARY - BATEA

SUBCATEGORY: Felted Fabric Processing CONTROL LEVEL: BATEA MODEL FLOW: 416 (0.11) cu m/day (mgd)

ANNUAL CAPACITY: 585 kkg DAILY CAPACITY: 2 kkg NUMBER OF MILLS REPRESENTED: 3

	Treatment Alternative						
	A	B	D	F	G	H	K
	Cost, thousands of dollars						
Investment Costs							
Preliminary Treatment							
Equipment	5	-	-	-	-	-	-
Construction	21	-	-	-	-	-	-
Activated Sludge							
Equipment	18	-	-	-	-	-	-
Construction	72	-	-	-	-	-	-
Chemical Coagulation							
Equipment	-	11	11	11	-	11	11
Construction	-	43	43	43	-	43	43
Vacuum Filtration							
Equipment	19	19	19	19	-	19	19
Construction	34	34	34	34	-	34	34
Dissolved Air Flotation							
Equipment	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-
Multi-Media Filtration							
Equipment	-	-	12	12	-	-	12
Construction	-	-	47	47	-	-	47
Activated Carbon							
Equipment	-	-	-	32	-	-	-
Construction	-	-	-	33	-	-	-
Ozonation							
Equipment	-	-	-	-	42	42	42
Construction	-	-	-	-	42	42	42
Monitoring	15	15	15	15	15	15	15
Engineering	21	15	21	27	13	24	29
Contingencies	28	18	27	37	15	31	40
Total Investment Costs	233	155	229	310	127	261	334

SUBCATEGORY: Felted Fabric Processing CONTROL LEVEL: BATEA MODEL FLOW: 416 (0.11) cu m/day (mgd)

Annual Costs

Capital	23	16	23	31	13	26	33
Depreciation	14	9	14	18	6	14	18
Useful Life (years)	15	15	15	16	20	17	17
O&M Labor	23	38	40	41	15	53	54
Employees (persons)	1.0	1.7	1.8	1.8	0.7	2.3	3.1
Maintenance	7	6	10	12	0.4	6	11
Sludge Disposal	3	1	1	4	-	1	1
Energy & Power	7	1	1	1	9	10	10
Chemicals: Polymer	-	-	-	-	-	-	-
Alum	-	2	2	2	-	2	2
Carbon	-	-	-	91	-	-	-
Monitoring	27	27	27	27	27	27	27
Total Annual Costs	104	100	118	227	70	139	156

Effluent Quality

Resulting Mass Loading

BOD5, kg/day	15	6	6	2	15	4	4
COD, kg/day	127	87	71	17	56	29	29
TSS, kg/day	40	25	10	4	40	10	4
Phenols, g/day	33	19	15	6	4	4	4
Chromium, g/day	-	-	-	-	-	-	-

Resulting Concentration

BOD5, mg/l	35	15	15	5	35	10	10
COD, mg/l	305	210	170	40	135	70	70
TSS, mg/l	95	60	25	10	95	25	10
Phenols, ug/l	80	45	35	15	10	10	10
Chromium, ug/l	-	-	-	-	-	-	-

prior to the activated sludge unit could be beneficial in reducing the load on the biological system so that it could remove organic matter more completely. In conclusion, if biological treatment were to be included, its most logical position is after preliminary treatment and prior to any additional processes. In other words, if biotreatment were to be included, the pretreatment systems would resemble the systems used by direct dischargers.

The benefits that would result from biotreatment as part of pretreatment follow. Since it duplicates the removal mechanisms of secondary POTW, it might seem at first glance to offer no benefits. One benefit is that it may accomplish removal of certain toxic pollutants, e.g., phenol, and cyanides that require an acclimated biomass. The continuous presence of such compounds due to higher concentrations could help maintain the state of acclimation. Acclimation could, at times, be lost at the POTW. Also, volatile toxic pollutants may be removed during aeration in a biological pretreatment process, and not be discharged to the POTW. The biological process coupled with that at the POTW, in effect, provide two stages of treatment and may effect greater removals than either alone. It should be noted that the above applies to some toxic pollutants, but not to all.

A second, and perhaps more important, benefit of biological pretreatment is that the level of dissolved organics would be reduced and the effectiveness of downstream activated carbon or ozonation units would be improved. On the other hand, chemical coagulation, with or without filtration, is believed to be effective in reducing the suspended and some of the dissolved organic content of textile mill wastewaters, although probably not as effectively as does activated sludge. A third benefit of biotreatment is that it would provide equalization and a separate unit for this purpose could be eliminated.

Among the disadvantages of including a biological process as part of pretreatment is that it duplicates the function of the POTW with only marginal benefits, if any, in terms of toxic pollutant control; it is relatively costly in terms of construction and operation; it may require much land, an unavailable commodity at many indirect-discharge mills; and it is a more difficult process to operate efficiently than are the physicochemical processes. It is also more affected by changes in temperature, pH, toxic materials, and the food supply balance. It also is unlikely to be effective for some of the toxic pollutants found in textile mill wastewaters, e.g., chloroform and trichloroethylene, and may, in fact, cause these and other volatile toxic pollutants to escape to the atmosphere.

Based on the above factors, it was concluded that the benefits of inclusion of biological treatment in the alternative pretreatment technologies presented here were outweighed by the disadvantages. It is believed that combinations of the five selected processes can be made to accomplish the desired results without biotreatment.

The alternatives for each level of control include screening and equalization along with one or a combination of the following technologies: chemical coagulation, multi-media filtration, dissolved air flotation, activated carbon adsorption, and ozonation. These five technologies are described previously in this section. Descriptions of screening and equalization are given below.

Screening. This technology utilizes mechanical fine screens to remove coarse suspended solids. Screening facilities include intersection of the existing sewer, pumping, and mecanical vibratory screens.

Equalization. Twelve hours detention and mixing by surface aerators are provided based on an analysis of the survey questionnaires. The cost estimates are based on lined earthen-wall basins with water depth of 3 meters (10 feet), freeboard of 1.5 meters (5 feet), and dike surface slopes of 3:1. The basins are square in plan.

Investment Costs and Annual Costs

The same bases were used for the investment and annual costs for the model indirect dischargers as previously described for the direct dischargers. As noted, the indirect dischargers sample less frequently and at fewer locations in their monitoring programs. The cost curves described previously and given in Figures VIII-1 through VIII-8 apply for indirect discharge mills also.

Model Plant Costs

As noted in the discussion of direct dischargers, model plant sizes were developed for various production ranges, corrected to full mill capacity, with the median water usage rates applied to derive raw wastewater flows. As shown in Table VIII-2, the model treatment plant sizes used for indirect dischargers are, in part, different from the sizes for the direct-discharge mills.

Cost Effectiveness Summaries

As with the existing direct dischargers, cost effectiveness summary sheets were developed for each model plant in the indirect discharge group to provide a synopsis of the cost analysis for each alternative end-of-pipe treatment technology. The summary sheets for indirect dischargers comprise Tables VIII-15 through VIII-26. The letter designations for the alternative technologies are the same for the direct and the indirect dischargers. In other words, Alternative C is multi-media filtration in both situations, etc.

TABLE VIII-15
MODEL PLANT CONTROL COST SUMMARY - PSES

SUBCATEGORY: Wool Scouring CONTROL LEVEL: PSES MODEL FLOW: 946 (0.25) cu m/day (mgd)

ANNUAL CAPACITY: 24,000 kkg DAILY CAPACITY: 81 kkg NUMBER OF MILLS REPRESENTED: 3

	Treatment Alternative			
	A	M	N	P
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	20	20	20
Construction	-	37	37	37
Chemical Coagulation				
Equipment	-	18	18	18
Construction	-	70	70	70
Vacuum Filtration				
Equipment	-	38	38	38
Construction	-	72	72	72
Dissolved Air Flotation				
Equipment	-	25	25	25
Construction	-	46	46	46
Multi-Media Filtration				
Equipment	-	-	19	-
Construction	-	-	77	-
Activated Carbon				
Equipment	-	-	300	-
Construction	-	-	300	-
Ozonation				
Equipment	-	-	-	80
Construction	-	-	-	80
Monitoring	-	15	15	15
Engineering	-	35	78	49
Contingencies	-	51	156	75
Total Investment Costs	-	427	1271	625

SUBCATEGORY: Wool Scouring CONTROL LEVEL: PSES MODEL FLOW: 946 (0.25) cu m/day (mgd)

Annual Costs				
Capital	-	43	127	62
Depreciation	-	26	66	34
Useful Life (years)	-	15	18	17
O&M Labor	-	57	71	73
Employees (persons)	-	2.5	3.1	3.3
Maintenance	-	14	24	15
Sludge Disposal	-	4	4	4
Energy & Power	-	6	12	27
Chemicals: Polymer	-	-	-	-
Alum	-	50	50	50
Carbon	-	-	16	-
Monitoring	-	13	13	13
Total Annual Costs	-	213	383	278
Effluent Quality				
		Resulting Mass Loading		
BOD5, kg/day	2179	57	19	52
COD, kg/day	6632	284	47	142
TSS, kg/day	3126	19	9	19
Phenols, g/day	-	-	-	-
Chromium, g/day	114	114	57	114
		Resulting Concentration		
BOD5, mg/l	2300	60	20	55
COD, mg/l	7000	300	50	150
TSS, mg/l	3300	20	10	20
Phenols, ug/l	-	-	-	-
Chromium, ug/l	120	120	60	120

TABLE VIII-16

MODEL PLANT CONTROL COST SUMMARY - PSES

SUBCATEGORY: Wool Finishing   CONTROL LEVEL: PSES   MODEL FLOW: 5,678 (1.5) cu m/day (mgd)

ANNUAL CAPACITY: 6,000 kkg   DAILY CAPACITY: 20 kkg   NUMBER OF MILLS REPRESENTED: 2

	Treatment Alternative					
	A	B	D	F	H	J
	Cost, thousands of dollars					
Investment Costs	A	B	D	F	H	J
Preliminary Treatment						
Equipment	-	49	49	49	49	49
Construction	-	92	92	92	92	92
Chemical Coagulation						
Equipment	-	50	50	50	50	-
Construction	-	200	200	200	200	-
Vacuum Filtration						
Equipment	-	19	19	19	19	19
Construction	-	34	34	34	34	34
Dissolved Air Flotation						
Equipment	-	-	-	-	-	-
Construction	-	-	-	-	-	-
Multi-Media Filtration						
Equipment	-	-	52	52	-	56
Construction	-	-	208	208	-	223
Activated Carbon						
Equipment	-	-	-	540	-	-
Construction	-	-	-	540	-	-
Ozonation						
Equipment	-	-	-	-	310	310
Construction	-	-	-	-	310	310
Monitoring	-	15	15	15	15	15
Engineering	-	45	66	145	93	96
Contingencies	-	69	108	270	162	166
Total Investment Costs	-	573	893	2214	1334	1370

SUBCATEGORY: Wool Finishing CONTROL LEVEL: PSES MODEL FLOW: 5,678 (1.5) cu m/day (mgd)

	A	B	D	F	H	J
Annual Costs						
Capital	-	57	89	221	133	137
Depreciation	-	35	55	115	69	76
Useful Life (years)	-	15	15	18	18	18
O&M Labor	-	92	104	128	126	114
Employees (persons)	-	4.1	4.6	5.7	5.6	5.0
Maintenance	-	42	68	86	47	46
Sludge Disposal	-	6	6	6	6	4
Energy & Power	-	13	14	45	139	133
Chemicals: Polymer	-	-	-	-	-	-
Alum	-	30	30	30	30	4
Carbon	-	-	-	99	-	-
Monitoring	-	13	13	13	13	13
Total Annual Costs	-	288	379	743	563	527
Effluent Quality						
	Resulting Mass Loading					
BOD5, kg/day	966	199	170	57	199	796
COD, kg/day	3411	1308	1308	341	568	1478
TSS, kg/day	341	85	57	57	85	57
Phenols, g/day	682	682	682	57	28	28
Chromium, g/day	2842	2842	2842	1421	2842	2842
	Resulting Concentration					
BOD5, mg/l	170	35	30	10	35	140
COD, mg/l	600	230	230	60	100	260
TSS, mg/l	60	15	10	10	15	10
Phenols, ug/l	120	120	120	10	5	5
Chromium, ug/l	500	500	500	500	500	500

TABLE VIII-17
MODEL PLANT CONTROL COST SUMMARY - PSES

SUBCATEGORY: Woven Fabric Finishing - Simple Processing CONTROL LEVEL: PSES MODEL FLOW: 946 (0.25) cu m/day (mgd)

ANNUAL CAPACITY: 3,600 kkg DAILY CAPACITY: 12 kkg NUMBER OF MILLS REPRESENTED: 26

	Treatment Alternative					
	A	B	D	F	H	J
	Cost, thousands of dollars					
Investment Costs						
Preliminary Treatment						
Equipment	-	20	20	20	20	20
Construction	-	37	37	37	37	37
Chemical Coagulation						
Equipment	-	18	18	18	18	-
Construction	-	70	70	70	70	-
Vacuum Filtration						
Equipment	-	19	19	19	19	19
Construction	-	34	34	34	34	34
Dissolved Air Flotation						
Equipment	-	-	-	-	-	-
Construction	-	-	-	-	-	-
Multi-Media Filtration						
Equipment	-	-	19	19	-	21
Construction	-	-	77	77	-	82
Activated Carbon						
Equipment	-	-	-	300	-	-
Construction	-	-	-	300	-	-
Ozonation						
Equipment	-	-	-	-	80	80
Construction	-	-	-	-	80	80
Monitoring	-	15	15	15	15	15
Engineering	-	24	34	78	39	40
Contingencies	-	32	46	136	56	58
Total Investment Costs	-	269	389	1123	468	486

SUBCATEGORY: Woven Fabric Finishing - Simple Processing CONTROL LEVEL: PSES MODEL FLOW: 946 (0.25) cu m/day (mgd)

Annual Costs						
Capital	-	27	39	112	47	49
Depreciation	-	16	24	55	25	25
Useful Life (years)	-	15	15	19	17	18
O&M Labor	-	52	55	66	69	67
Employees (persons)	-	2.3	2.5	2.9	3.0	3.0
Maintenance	-	10	18	21	11	14
Sludge Disposal	-	2	3	3	2	1
Energy & Power	-	4	4	9	25	24
Chemicals: Polymer	-	-	-	-	-	-
Alum	-	5	5	5	5	0.7
Carbon	-	-	-	16	-	-
Monitoring	-	13	13	13	13	13
Total Annual Costs	-	129	161	300	197	194
Effluent Quality						
				Resulting Mass Loading		
BOD5, kg/day	255	38	38	14	38	208
COD, kg/day	853	256	256	66	114	370
TSS, kg/day	57	14	9	9	14	9
Phenols, g/day	47	47	47	5	5	5
Chromium, g/day	38	38	38	19	38	38
				Resulting Concentration		
BOD5, mg/l	270	40	40	15	40	220
COD, mg/l	900	270	270	70	120	390
TSS, mg/l	60	15	10	10	15	10
Phenols, ug/l	50	50	50	5	5	5
Chromium, ug/l	40	40	40	20	40	40

TABLE VIII-18
MODEL PLANT CONTROL COST SUMMARY - PSES

SUBCATEGORY: Woven Fabric Finishing - Complex Processing   CONTROL LEVEL: PSES   MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

ANNUAL CAPACITY: 7,900 kkg   DAILY CAPACITY: 26 kkg   NUMBER OF MILLS REPRESENTED: 12

	Treatment Alternative				
	A	B	D	F	H
	Cost, thousands of dollars				
Investment Costs					
Preliminary Treatment					
Equipment	-	29	29	29	29
Construction	-	55	55	55	55
Chemical Coagulation					
Equipment	-	30	30	30	30
Construction	-	120	120	120	120
Vacuum Filtration					
Equipment	-	19	19	19	19
Construction	-	34	34	34	34
Dissolved Air Flotation					
Equipment	-	-	-	-	-
Construction	-	-	-	-	-
Multi-Media Filtration					
Equipment	-	-	30	30	-
Construction	-	-	120	120	-
Activated Carbon					
Equipment	-	-	-	340	-
Construction	-	-	-	340	-
Ozonation					
Equipment	-	-	-	-	150
Construction	-	-	-	-	150
Monitoring	-	15	15	15	15
Engineering	-	33	44	98	55
Contingencies	-	45	68	170	90
Total Investment Costs	-	380	564	1400	747

SUBCATEGORY: Woven Fabric Finishing - Complex Processing   CONTROL LEVEL: PSES   MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

Annual Costs					
Capital	-	38	56	140	75
Depreciation	-	23	35	72	41
Useful Life (years)	-	15	15	18	17
O&M Labor	-	68	75	94	87
Employees (persons)	-	3.0	3.4	4.1	3.8
Maintenance	-	20	34	40	22
Sludge Disposal	-	5	5	5	5
Energy & Power	-	6	7	19	57
Chemicals: Polymer	-	-	-	-	-
Alum	-	12	12	12	12
Carbon	-	-	-	40	-
Monitoring	-	13	13	13	13
Total Annual Costs	-	185	237	435	312
Effluent Quality					
			Resulting Mass Loading		
BOD_5, kg/day	796	102	91	34	102
COD, kg/day	2501	637	614	159	296
TSS, kg/day	250	68	23	23	68
Phenols, g/day	114	114	114	11	11
Chromium, g/day	250	250	250	125	250
			Resulting Concentration		
BOD_5, mg/l	350	45	40	15	45
COD, mg/l	1100	280	270	70	130
TSS, mg/l	110	30	10	10	30
Phenols, ug/l	50	50	50	5	5
Chromium, ug/l	110	110	110	55	110

TABLE VIII-19
MODEL PLANT CONTROL COST SUMMARY - PSES

SUBCATEGORY: Woven Fabric Finishing-Complex Processing Plus Desizing   CONTROL LEVEL: PSES   MODEL FLOW: 5,678 (1.5) cu m/day (mgd)

ANNUAL CAPACITY: 15,000 kkg   DAILY CAPACITY: 50 kkg   NUMBER OF MILLS REPRESENTED: 7

	Treatment Alternative				
	A	B	D	F	H
	Cost, thousands of dollars				
Investment Costs					
Preliminary Treatment					
Equipment	-	49	49	49	49
Construction	-	92	92	92	92
Chemical Coagulation					
Equipment	-	50	50	50	50
Construction	-	200	200	200	200
Vacuum Filtration					
Equipment	-	23	23	23	23
Construction	-	42	42	42	42
Dissolved Air Flotation					
Equipment	-	-	-	-	-
Construction	-	-	-	-	-
Multi-Media Filtration					
Equipment	-	-	52	52	-
Construction	-	-	208	208	-
Activated Carbon					
Equipment	-	-	-	540	-
Construction	-	-	-	540	-
Ozonation					
Equipment	-	-	-	-	310
Construction	-	-	-	-	310
Monitoring	-	13	13	13	13
Engineering	-	46	67	146	94
Contingencies	-	70	109	271	163
Total Investment Costs	-	585	905	2226	1346

SUBCATEGORY: Woven Fabric Finishing- Complex Processing Plus Desizing CONTROL LEVEL: PSES MODEL FLOW: 5,678 (1.5) cu m/day (mgd)

Annual Costs					
Capital	-	58	90	223	135
Depreciation	-	36	56	116	70
Useful Life (years)	-	15	15	18	18
O&M Labor	-	92	104	140	114
Employees (persons)	-	4.1	4.6	6.2	5.1
Maintenance	-	42	68	86	47
Sludge Disposal	-	7	8	7	7
Energy & Power	-	13	14	45	139
Chemicals: Polymer	-	-	-	-	-
Alum	-	30	30	30	30
Carbon	-	-	-	99	-
Monitoring	-	13	13	13	13
Total Annual Costs	-	291	383	759	555
Effluent Quality					
				Resulting Mass Loading	
BOD5, kg/day	2388	227	170	57	227
COD, kg/day	7049	853	796	199	398
TSS, kg/day	853	199	57	57	199
Phenols, g/day	853	853	853	85	57
Chromium, g/day	568	568	568	284	568
				Resulting Concentration	
BOD5, mg/l	420	40	30	10	40
COD, mg/l	1240	150	140	35	70
TSS, mg/l	150	35	10	10	35
Phenols, ug/l	150	150	150	15	10
Chromium, ug/l	100	100	100	50	100

TABLE VIII-20
MODEL PLANT CONTROL COST SUMMARY - PSES

SUBCATEGORY: Knit Fabric Finishing - Simple Processing   CONTROL LEVEL: PSES   MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

ANNUAL CAPACITY: 5,600 kkg   DAILY CAPACITY: 18.6 kkg   NUMBER OF MILLS REPRESENTED: 34

	Treatment Alternative					
	A	B	D	F	H	J
	Cost, thousands of dollars					
Investment Costs						
Preliminary Treatment						
Equipment	-	29	29	29	29	29
Construction	-	55	55	55	55	55
Chemical Coagulation						
Equipment	-	30	30	30	30	-
Construction	-	120	120	120	120	-
Vacuum Filtration						
Equipment	-	19	19	19	19	19
Construction	-	34	34	34	34	34
Dissolved Air Flotation						
Equipment	-	-	-	-	-	-
Construction	-	-	-	-	-	-
Multi-Media Filtration						
Equipment	-	-	30	30	-	32
Construction	-	-	120	120	-	130
Activated Carbon						
Equipment	-	-	-	340	-	-
Construction	-	-	-	340	-	-
Ozonation						
Equipment	-	-	-	-	150	150
Construction	-	-	-	-	150	150
Monitoring	-	15	15	15	15	15
Engineering	-	33	44	98	55	56
Contingencies	-	45	68	170	90	92
Total Investment Costs	-	380	564	1400	747	762

SUBCATEGORY: Knit Fabric Finishing - Simple Processing CONTROL LEVEL: PSES MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

Annual Costs						
Capital	-	38	56	140	75	76
Depreciation	-	23	35	72	41	39
Useful Life (years)	-	15	15	18	17	18
O&M Labor	-	68	75	94	87	87
Employees (persons)	-	3.0	2.8	4.2	3.9	3.9
Maintenance	-	20	34	40	22	24
Sludge Disposal	-	4	4	4	4	2
Energy & Power	-	6	7	19	57	54
Chemicals: Polymer	-	-	-	-	-	-
Alum	-	12	12	12	12	2
Carbon	-	-	40	-	-	-
Monitoring	-	13	13	13	13	13
Total Annual Costs	-	184	236	434	311	297
Effluent Quality						
				Resulting Mass Loading		
BOD5, kg/day	478	91	91	34	91	409
COD, kg/day	1978	591	591	148	273	864
TSS, kg/day	114	34	23	23	34	23
Phenols, g/day	250	250	250	23	11	11
Chromium, g/day	182	182	182	91	182	182
				Resulting Concentration		
BOD5, mg/l	210	40	40	15	40	180
COD, mg/l	870	260	260	65	120	380
TSS, mg/l	50	15	10	10	15	10
Phenols, ug/l	110	110	110	10	5	5
Chromium, ug/l	80	80	80	40	80	80

TABLE VIII-21
MODEL PLANT CONTROL COST SUMMARY - PSES

SUBCATEGORY: Knit Fabric Finishing- Complex Processing   CONTROL LEVEL: PSES   MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

ANNUAL CAPACITY: 5,600 kkg   DAILY CAPACITY: 18.6 kkg   NUMBER OF MILLS REPRESENTED: 19

	Treatment Alternative					
	A	B	D	F	H	J
	Cost, thousands of dollars					
Investment Costs						
Preliminary Treatment						
Equipment	-	29	29	29	29	29
Construction	-	55	55	55	55	55
Chemical Coagulation						
Equipment	-	30	30	30	30	-
Construction	-	120	120	120	120	-
Vacuum Filtration						
Equipment	-	19	19	19	19	19
Construction	-	34	34	34	34	34
Dissolved Air Flotation						
Equipment	-	-	-	-	-	-
Construction	-	-	-	-	-	-
Multi-Media Filtration						
Equipment	-	-	30	30	-	32
Construction	-	-	120	120	-	130
Activated Carbon						
Equipment	-	-	-	340	-	-
Construction	-	-	-	340	-	-
Ozonation						
Equipment	-	-	-	-	150	150
Construction	-	-	-	-	150	150
Monitoring	-	15	15	15	15	15
Engineering	-	33	44	98	55	56
Contingencies	-	45	68	170	90	92
Total Investment Costs	-	380	564	1400	747	762

SUBCATEGORY: Knit Fabric Finishing-Complex Processing CONTROL LEVEL: PSES MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

Annual Costs

Capital	-	38	56	140	75	76
Depreciation	-	23	35	72	41	39
Useful Life (years)	-	15	15	18	17	18
O&M Labor	-	68	75	94	87	87
Employees (persons)	-	3.0	3.3	4.2	3.9	3.9
Maintenance	-	20	34	40	22	24
Sludge Disposal	-	4	5	5	4	2
Energy & Power	-	6	7	19	57	54
Chemicals: Polymer	-	-	-	-	-	-
Alum	-	12	12	12	12	2
Carbon	-	-	-	40	-	-
Monitoring	-	13	13	13	13	13
Total Annual Costs	-	184	237	435	311	297

Effluent Quality

				Resulting Mass Loading		
BOD_5, kg/day	614	91	91	34	91	500
COD, kg/day	1796	591	591	148	273	773
TSS, kg/day	136	34	23	23	34	23
Phenols, g/day	227	227	227	23	11	11
Chromium, g/day	182	182	182	91	182	182
				Resulting Concentration		
BOD_5, mg/l	270	40	40	15	40	220
COD, mg/l	790	260	260	65	120	340
TSS, mg/l	60	15	10	10	15	10
Phenols, ug/l	100	100	100	10	5	5
Chromium, ug/l	80	80	80	40	80	80

TABLE VIII-22
MODEL PLANT CONTROL COST SUMMARY - PSES

SUBCATEGORY: Knit Fabric Finishing - Hosiery Products CONTROL LEVEL: PSES MODEL FLOW: 946 (0.25) cu m/day (mgd)

ANNUAL CAPACITY: 4,100 kkg DAILY CAPACITY: 13.6 kkg NUMBER OF MILLS REPRESENTED: 7

	Treatment Alternative					
	A	B	D	F	H	J
	Cost, thousands of dollars					
Investment Costs						
Preliminary Treatment						
Equipment	-	20	20	20	20	20
Construction	-	37	37	37	37	37
Chemical Coagulation						
Equipment	-	18	18	18	18	-
Construction	-	70	70	70	70	-
Vacuum Filtration						
Equipment	-	19	19	19	19	19
Construction	-	34	34	34	34	34
Dissolved Air Flotation						
Equipment	-	-	-	-	-	-
Construction	-	-	-	-	-	-
Multi-Media Filtration						
Equipment	-	-	19	19	-	21
Construction	-	-	77	77	-	82
Activated Carbon						
Equipment	-	-	-	300	-	-
Construction	-	-	-	300	-	-
Ozonation						
Equipment	-	-	-	-	80	80
Construction	-	-	-	-	80	80
Monitoring	-	15	15	15	15	15
Engineering	-	24	32	78	39	40
Contingencies	-	32	46	136	56	58
Total Investment Costs	-	269	387	1123	468	486

SUBCATEGORY: Knit Fabric Finishing - Hosiery Products CONTROL LEVEL: PSES MODEL FLOW: 946 (0.25) cu m/day (mgd)

Annual Costs						
Capital	-	27	39	112	47	49
Depreciation	-	16	24	55	25	28
Useful Life (years)	-	15	15	19	17	18
O&M Labor	-	52	55	66	69	67
Employees (persons)	-	2.3	2.5	2.9	3.0	3.0
Maintenance	-	10	18	21	11	14
Sludge Disposal	-	2	3	3	2	1
Energy & Power	-	4	4	9	25	24
Chemicals: Polymer	-	-	-	-	-	-
Alum	-	5	5	5	5	0.7
Carbon	-	-	-	16	-	-
Monitoring	-	13	13	13	13	13
Total Annual Costs	-	129	161	300	197	197
Effluent Quality						
			Resulting Mass Loading			
BOD_5, kg/day	303	52	47	19	47	256
COD, kg/day	1298	275	265	66	123	568
TSS, kg/day	76	19	9	9	19	9
Phenols, g/day	57	57	57	5	5	5
Chromium, g/day	76	76	76	38	76	76
			Resulting Concentration			
BOD_5, mg/l	320	55	50	20	50	270
COD, mg/l	1370	290	280	70	130	600
TSS, mg/l	80	20	10	10	20	10
Phenols, ug/l	60	60	60	5	5	5
Chromium, ug/l	80	80	80	40	80	80

TABLE VIII-23
MODEL PLANT CONTROL COST SUMMARY - PSES

SUBCATEGORY: Carpet Finishing   CONTROL LEVEL: PSES   MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

ANNUAL CAPACITY: 14,600 kkg   DAILY CAPACITY: 49 kkg   NUMBER OF MILLS REPRESENTED: 16

	Treatment Alternative					
	A	B	D	F	H	J
	Cost, thousands of dollars					
Investment Costs						
Preliminary Treatment						
Equipment	-	29	29	29	29	29
Construction	-	55	55	55	55	55
Chemical Coagulation						
Equipment	-	30	30	30	30	-
Construction	-	120	120	120	120	-
Vacuum Filtration						
Equipment	-	19	19	19	19	19
Construction	-	34	34	34	34	34
Dissolved Air Flotation						
Equipment	-	-	-	-	-	-
Construction	-	-	-	-	-	-
Multi-Media Filtration						
Equipment	-	-	30	30	-	32
Construction	-	-	120	120	-	130
Activated Carbon						
Equipment	-	-	-	340	-	-
Construction	-	-	-	340	-	-
Ozonation						
Equipment	-	-	-	-	150	150
Construction	-	-	-	-	150	150
Monitoring	-	15	15	15	15	15
Engineering	-	33	44	98	55	56
Contingencies	-	45	68	170	90	92
Total Investment Costs	-	380	564	1400	747	762

SUBCATEGORY: Carpet Finishing   CONTROL LEVEL: PSES   MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

Annual Costs						
Capital	-	38	56	140	75	76
Depreciation	-	23	35	68	41	39
Useful Life (years)	-	15	15	19	17	18
O&M Labor	-	68	76	95	77	77
Employees (persons)	-	3.0	3.3	4.2	3.5	3.4
Maintenance	-	20	34	40	22	24
Sludge Disposal	-	4	5	5	4	2
Energy & Power	-	6	6	19	57	54
Chemicals: Polymer	-	-	-	-	-	-
Alum	-	12	12	12	12	2
Carbon	-	-	-	40	-	-
Monitoring	-	13	13	13	13	13
Total Annual Costs	-	184	236	432	301	287
Effluent Quality						
				Resulting Mass Loading		
BOD5, kg/day	1000	68	57	23	68	864
COD, kg/day	2706	386	364	91	170	1182
TSS, kg/day	159	45	23	23	45	23
Phenols, g/day	296	296	296	34	11	11
Chromium, g/day	68	68	68	34	68	68
				Resulting Concentration		
BOD5, mg/l	440	30	25	10	30	280
COD, mg/l	1190	170	160	40	75	520
TSS, mg/l	70	20	10	10	20	10
Phenols, ug/l	130	130	30	15	30	30
Chromium, ug/l	30	30	30	15	30	30

TABLE VIII-24
MODEL PLANT CONTROL COST SUMMARY - PSES

SUBCATEGORY: Stock & Yarn Finishing CONTROL LEVEL: PSES MODEL FLOW: 946 (0.25) cu m/day (mgd)

ANNUAL CAPACITY: 2,800 kkg DAILY CAPACITY: 9.4 kkg NUMBER OF MILLS REPRESENTED: 40

	Treatment Alternative					
	A	B	D	F	H	J
	Cost, thousands of dollars					
Investment Costs						
Preliminary Treatment						
Equipment	-	20	20	20	20	20
Construction	-	37	37	37	37	37
Chemical Coagulation						
Equipment	-	18	18	18	18	-
Construction	-	70	70	70	70	-
Vacuum Filtration						
Equipment	-	19	19	19	19	19
Construction	-	34	34	34	34	34
Dissolved Air Flotation						
Equipment	-	-	-	-	-	-
Construction	-	-	-	-	-	-
Multi-Media Filtration						
Equipment	-	-	19	19	-	21
Construction	-	-	77	77	-	82
Activated Carbon						
Equipment	-	-	-	300	-	-
Construction	-	-	-	300	-	-
Ozonation						
Equipment	-	-	-	-	80	80
Construction	-	-	-	-	80	80
Monitoring	-	15	15	15	15	15
Engineering	-	24	32	78	39	40
Contingencies	-	32	46	136	56	58
Total Investment Costs	-	269	387	1123	468	486

SUBCATEGORY: Stock & Yarn Finishing   CONTROL LEVEL: PSES   MODEL FLOW: 946 (0.25) cu m/day (mgd)

Annual Costs

Capital	-	27	39	112	47	49
Depreciation	-	16	24	55	25	25
Useful Life (years)	-	15	15	19	17	18
O&M Labor	-	52	55	66	69	67
Employees (persons)	-	2.3	2.5	2.9	3.0	3.0
Maintenance	-	10	18	21	11	14
Sludge Disposal	-	2	2	2	2	1
Energy & Power	-	4	4	9	25	23
Chemicals: Polymer	-	-	-	-	-	-
Alum	-	5	5	5	5	0.6
Carbon	-	-	-	16	-	-
Monitoring	-	13	13	13	13	13
Total Annual Costs	-	129	160	299	197	193

Effluent Quality

		Resulting Mass Loading				
BOD5, kg/day	170	33	33	9	33	142
COD, kg/day	644	227	227	57	104	284
TSS, kg/day	38	9	9	9	9	9
Phenols, g/day	161	161	161	19	9	9
Chromium, g/day	95	95	95	47	95	95

		Resulting Concentration				
BOD5, mg/l	180	35	35	10	35	150
COD, mg/l	680	240	240	60	110	300
TSS, mg/l	40	10	10	10	10	10
Phenols, ug/l	170	170	170	20	10	10
Chromium, ug/l	100	100	100	50	100	100

TABLE VIII-25
MODEL PLANT CONTROL COST SUMMARY - PSES

SUBCATEGORY: Nonwoven Manufacturing CONTROL LEVEL: PSES MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

ANNUAL CAPACITY: 17,000 kkg DAILY CAPACITY: 57 kkg NUMBER OF MILLS REPRESENTED: 5

	Treatment Alternative					
	A	B	D	F	H	J
	Cost, thousands of dollars					
Investment Costs						
Preliminary Treatment						
Equipment	-	29	29	29	29	29
Construction	-	55	55	55	55	55
Chemical Coagulation						
Equipment	-	30	30	30	30	-
Construction	-	120	120	120	120	-
Vacuum Filtration						
Equipment	-	19	19	19	19	19
Construction	-	34	34	34	34	34
Dissolved Air Flotation						
Equipment	-	-	-	-	-	-
Construction	-	-	-	-	-	-
Multi-Media Filtration						
Equipment	-	-	30	30	-	32
Construction	-	-	120	120	-	130
Activated Carbon						
Equipment	-	-	-	340	-	-
Construction	-	-	-	340	-	-
Ozonation						
Equipment	-	-	-	-	150	150
Construction	-	-	-	-	150	150
Monitoring	-	15	15	15	15	15
Engineering	-	33	44	98	55	56
Contingencies	-	45	68	170	90	92
Total Investment Costs	-	380	564	1400	747	762

SUBCATEGORY: Nonwoven Manufacturing CONTROL LEVEL: PSES MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

<u>Annual Costs</u>

Capital	-	38	56	140	75	76
Depreciation	-	23	35	72	38	39
Useful Life (years)	-	15	15	18	18	18
O&M Labor	-	68	75	94	87	87
Employees (persons)	-	3.0	3.3	4.2	3.9	3.9
Maintenance	-	20	34	40	22	24
Sludge Disposal	-	4	5	5	4	2
Energy & Power	-	6	6	19	57	54
Chemicals: Polymer	-	-	-	-	-	-
Alum	-	12	12	12	12	2
Carbon	-	-	-	40	-	-
Monitoring	-	13	13	13	13	13
Total Annual Costs	-	184	236	435	308	297

<u>Effluent Quality</u>

				Resulting Mass Loading		
BOD5, kg/day	409	80	68	23	80	318
COD, kg/day	5367	591	568	136	273	2365
TSS, kg/day	182	45	23	23	45	23
Phenols, g/day	91	91	91	11	-	-
Chromium, g/day	23	23	23	11	23	23

				Resulting Concentration		
BOD5, mg/l	180	35	30	10	35	140
COD, mg/l	2360	260	250	60	120	1040
TSS, mg/l	80	20	10	10	20	10
Phenols, ug/l	40	40	40	5	-	-
Chromium, ug/l	10	10	10	5	10	10

TABLE VIII-26
MODEL PLANT CONTROL COST SUMMARY - PSES

SUBCATEGORY: Felted Fabric Processing CONTROL LEVEL: PSES MODEL FLOW: 946 (0.25) cu m/day (mgd)

ANNUAL CAPACITY: 1,300 kkg DAILY CAPACITY: 4.4 kkg NUMBER OF MILLS REPRESENTED: 5

	Treatment Alternative				
	A	B	D	F	H
	Cost, thousands of dollars				
Investment Costs					
Preliminary Treatment					
Equipment	-	20	20	20	20
Construction	-	37	37	37	37
Chemical Coagulation					
Equipment	-	18	18	18	18
Construction	-	70	70	70	70
Vacuum Filtration					
Equipment	-	19	19	19	19
Construction	-	34	34	34	34
Dissolved Air Flotation					
Equipment	-	-	-	-	-
Construction	-	-	-	-	-
Multi-Media Filtration					
Equipment	-	-	19	19	-
Construction	-	-	77	77	-
Activated Carbon					
Equipment	-	-	-	300	-
Construction	-	-	-	300	-
Ozonation					
Equipment	-	-	-	-	80
Construction	-	-	-	-	80
Monitoring	-	15	15	15	15
Engineering	-	24	32	78	37
Contingencies	-	32	46	136	56
Total Investment Costs	-	269	387	1123	465

SUBCATEGORY: Felted Fabric Processing CONTROL LEVEL: PSES MODEL FLOW: 946 (0.25) cu m/day (mgd)

Annual Costs					
Capital	-	27	39	112	47
Depreciation	-	16	24	55	24
Useful Life (years)	-	15	15	19	18
O&M Labor	-	52	55	66	69
Employees (persons)	-	2.3	2.5	2.9	3.0
Maintenance	-	10	18	21	11
Sludge Disposal	-	3	3	3	3
Energy & Power	-	4	4	9	24
Chemicals: Polymer	-	-	-	-	-
Alum	-	5	5	5	5
Carbon	-	-	-	16	-
Monitoring	-	13	13	13	13
Total Annual Costs	-	130	161	300	196
Effluent Quality					
				Resulting Mass Loading	
BOD5, kg/day	190	38	33	9	38
COD, kg/day	521	208	199	47	95
TSS, kg/day	114	24	9	9	24
Phenols, g/day	550	550	550	57	24
Chromium, g/day	-	-	-	-	-
				Resulting Concentration	
BOD5, mg/l	200	40	35	10	40
COD, mg/l	550	220	210	50	100
TSS, mg/l	120	25	10	10	25
Phenols, ug/l	580	580	580	60	25
Chromium, ug/l	-	-	-	-	-

Also shown on the summary sheets are the estimated effluent qualities resulting from each technology when applied in each textile industry subcategory. That the values of some of the effluent pollutant parameters are different from those for the direct dischargers reflects the different influent concentrations resulting from the absence of biological treatment in the pretreatment alternatives.

NEW SOURCES

Before discussion, introductory comments that apply to both groups are appropriate. The term "new source" is defined in the Act to mean "any source, the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance." In addition to the control measures available to existing sources, changes in manufacturing methods and equipment, more extensive use of in-plant control measures and water recycling, and different end-of-pipe technologies may be available to new sources. Such additional opportunities in the textile industry were evaluated based on available information. Compliance dates differ for new and existing sources.

Textile industry sources indicate that very few new mills have been constructed in the past few years. Consequently, there are relatively few sources of data on water consumption rates, in-plant control measures, and alternative manufacturing methods in use in new mills.

Zero Discharge

One of the solutions that is economically available to some industrial plants is complete elimination of liquid process-related waste discharges through in-plant measures, advanced waste treatment, and/or complete water recycle programs. There is no evidence available that such a solution is generally available to new sources in the Textile Mill Point Source category. While much research is under way aimed at conservation and reuse of certain materials, recovery of heat energy, and reduction of water usage in a few processes, there are no typical textile dyeing and finishing mills that are presently able to approach zero discharge of process-related wastewaters. Exceptions to this statement may include some mills in Subcategory 3 that contain all wastes for land disposal rather than discharge to the sewer. There may also be a few mills in other subcategories that have been able to eliminate discharges of process-related wastes because of some unique characteristics of their operation, but they do not represent most mills in their subcategory.

In conclusion, the available information indicates that some form of end-of-pipe treatment of textile mill wastewaters will be required for the forseeable future, and that zero discharge cannot be included as a control measure that is technically or economically available. Before moving to consideration of end-of-pipe measures, the importance of in-plant measures should be stressed again as a means of reducing treatment costs. Treatment for relatively small concentrations of toxic pollutants in waste streams can often be very costly compared to measures to eliminate their presence in the waste discharge initially. In-plant control measures should be considered first in evaluating solutions to waste control problems.

Water Usage Rates

In the past, the textile industry has done much to reduce water consumption in its manufacturing operations. It is expected that this trend will continue in the future, with water usage rates (l/kg or gal/lb) gradually declining. For the cost estimates for new sources in this report, however, the water usage rates are the same as those for existing sources. There were no data available by which to estimate what future usage rates may be for different subcategories and it was determined that existing usage rates would be most appropriate.

Control Measures

An opportunity that is potentially available to new sources is the separation of drainage piping in new mills so that waste streams with significant amounts of toxic pollutants can be segregated from those without. The former could then be subjected to appropriate advanced waste treatment processes with possibly improved efficiencies and reduced costs due to the smaller volume of flow compared to treating the entire volume of wastewater in the advanced processes.

A review of the principal sources of toxic pollutants in theoretically typical mills in each subcategory was carried out based on the available information about the chemicals used today in the industry. The major sources appear to be certain dyes, dye carriers, solvents, preservatives, and finishing chemicals. It was assumed that waste streams containing significant amounts of toxic pollutants would originate from dyeing and rinsing, application of functional finishes, and solvent scouring operations. Waste streams from bleaching, mercerizing, scouring, acid treatment, and fulling and the associated rinses were assumed to be free of toxic pollutants except as tramp impurities in some chemicals. It is recognized that some additives presently used in these last listed operations may include toxic pollutants. It was assumed that chemicals without toxic pollutants could be substituted for these additives and for other preservatives, disinfectants, and plant sanitary compounds presently in use. Laboratory wastes were assumed to be included in the toxic pollutant drainage system.

Based on available data, it was estimated that the toxic pollutant waste streams varied from about 10 percent to virtually 100 percent of the total process-related waste flow among the "typical" mills in the various subcategories. For the purposes of the cost estimates for new sources, it was assumed that about two-thirds of the total waste stream would contain significant levels of toxic pollutants for all subcategories. The precise flow split used varies slightly depending upon the total model plant flow volume used.

The above assumptions were introduced in order to develop reasonable cost estimates for new sources that are comparable to those for existing sources. It is believed that further refinement of the assumptions was not warranted in terms of the limited available information about the sources of toxic pollutants in textile mills or in terms of improved accuracy of the estimated costs. The basic premise is that savings in treatment costs, for larger systems, at least, will more than offset the costs of installing and operating segregated drainage systems for most new sources in the industry.

End-of-Pipe Technologies

The alternative end-of-pipe control technologies that are available for existing sources cover the spectrum of processes that are presently available for new sources. There is presently insufficient information available by which to evaluate the efficiency of steam stripping textile mill wastewaters as a means of removing low concentrations of volatile toxic pollutants that are refractory to other treatment processes.

Each of the alternative end-of-pipe technologies described prevously for existing sources was evaluated technically for application to new sources. It was concluded that alternatives comprising treatment trains similar to alternatives D, E, and F (Table VIII-1) were suitable for use with new sources. Alternatives like B and C were judged not to be cost effective because they would require prior treatment of the total waste flow by the equivalent of BPT and would not provide complete treatment of pollutants. Alternatives like G, H, J, and K were also rejected because of the requirement for prior BPT-level treatment of the whole waste stream and less than optimal removal of organic toxic pollutants.

Alternatives R, S, and T are designated for new sources and are roughly equivalent to Alternatives D, E, and F, respectively. For each of these three alternatives, comparisons at selected total flow levels were made between the costs of treating segregated vs combined flow streams, based on the assumption that two-thirds of the total flow required treatment to reduce toxic pollutants. It was determined that segregation was significantly cheaper for Alternatives S and T for direct dischargers and for all three alternatives for indirect dischargers.

NEW DIRECT DISCHARGE SOURCES

In-Plant Control Measures

As indicated elsewhere in this section, in-plant control measures will become increasingly important in reducing end-of-pipe treatment costs in all textile mills and especially in new sources. New mills should be designed for pollution control in terms of manufacturing processes and equipment selection. Design should include measures to contain spills, require dry cleaning methods, and incorporate instrumentation and other measures to conserve water. The benefits and costs of segregating drains should be carefully evaluated so that potentially toxic waste streams can be handled specifically and at minimum cost.

As with the existing direct discharge sources, the treatment alternatives do not include any in-plant control measures.

Selected End-of-Pipe Technologies

Three alternative end-of-pipe treatment technologies are available for direct discharging new sources in the textile mill category. Alternative R (equivalent to Alternative D for existing sources) comprises BPT, or its equivalent, plus chemical coagulation, sedimentation, and multi-media filtration of the total (unsegregated) waste stream. Segregation is not cost-effective for this alternative because the entire waste stream must receive BPT-level treatment to reduce the concentrations of conventional organic pollutants sufficiently to permit discharge to a receiving water. Prior treatment by BPT should improve the efficiency and/or lower the costs of the advanced treatment processes.

Alternative S provides screening, equalization, multi-media filtration, and granular activated carbon adsorption of the toxic pollutant waste stream prior to discharge to the receiving water. The remaining waste streams, without toxic pollutants, are subjected to conventional, 8-hour aeration period activated sludge. For total mill flows of 946 cu m/day (0.25 mgd) and less, the toxic pollutant waste streams are not segregated. It was judged that the smaller savings that would result from segregated treatment would not offset the costs of separated drainage systems. The total waste stream is treated by 24-hour activated sludge, filtration, and carbon adsorption.

Alternative T combines the processes of Alternatives R and S and should provide effective pollutant removals for discharge to receiving waters. The segregated toxic pollutant waste stream is treated in a train comprising screening, equalization, chemical coagulation and sedimentation, multi-media filtration, and granular activated carbon adsorption prior to discharge to the receiving water. The remaining waste streams are treated by conventional 8-hour activated sludge with prior screening and return of biomass from a secondary clarifier. For total mill flows of 946 cu m/day (0.25 mgd) and less, the toxic pollutant waste streams are not segregated, and the total flow is treated by 24-hour activated sludge followed by chemical coagulation, sedimentation, multi-media filtration, and carbon adsorption.

The three alternatives are described in Table VIII-27.

For all alternatives, thickened sludges are dewatered by vacuum filtration prior to removal to disposal in off-site sanitary landfill. An additional benefit of segregating the toxic pollutant waste streams is that the resulting sludges can be handled separately.

All but one of the individual processes comprising the three alternatives are described previously in this section. Screening and equalization are described under existing indirect dischargers.

Activated Sludge. Conventional activated sludge providing 8-hours detention in the aeration basin is used for non-toxic pollutant waste streams when waste segregation is assumed (Alternatives S and T). Extended-aeration activated sludge (24-hours aeration) is used for unsegregated waste streams (Alternative R and smaller mill flows for Alternatives S and T).

Investment Costs and Annual Costs

The same bases were used for the investment and annual costs for the model direct new sources as previously described for existing direct and indirect dischargers. Screening and equalization are covered under existing indirect dischargers. Cost curves were also presented earlier in this section (Figures VIII-1 through VIII-8).

Total installed costs are broken into equipment and construction fractions as follows:

Process	Equipment	Construction
Activated Sludge	20%	80%

Land Costs

Land requirements for waste treatment facilities will vary depending upon the wastewater flow and whether or not segregation of waste streams is instituted. The activated sludge process will dictate the overall land needs in the larger faclities and they could range up to 5 hectares (12.4 acres) or more, depending upon detention period,

TABLE VIII-27

ALTERNATIVE END-OF-PIPE-TREATMENT TECHNOLOGIES
NEW SOURCES - DIRECT DISCHARGE

Technology	Description
A	No treatment
R	Screening, 24-hour extended-aeration activated sludge with solids recycle, chemical coagulation, sedimentation, and multi-media filtration.
S	Larger flows: Priority pollutant stream - Screening, equalization, multi-media filtration, and granular activated carbon adsorption. Other streams - Screening and 8-hour activated sludge with solids recycle.
	Smaller flows: Total mill waste flow - Screening, 24-hour extended-aeration activated sludge with solids recycle, multi-media filtration and granular activated carbon adsorption.
T	Larger flows: Priority pollutant stream - Screening, equalization, chemical coagulation, sedimentation, multi-media filtration, and granular activated carbon adsorption. Other streams - Screening and 8-hour activated sludge with solids recycle.
	Smaller flows: Total mill waste flow - Screening, 24-hour extended-aeration activated sludge with solids recycle, chemical coagulation, sedimentation, multi-media filtration, and granular activated carbon adsorption.

water depth, and type of construction used for side walls. The land requirements for wastewater treatment facilities would be included in the planning for the new mill site.

Model Plant Costs

For new direct discharge sources, one representative model plant size was selected for each subcategory from among the model plant sizes developed for existing sources (Table VIII-2). As noted earlier, no adjustment was made for improvements in water conservation practices in new mills.

It was determined that it was very unlikely that new Wool Scouring mills will be constructed in the forseeable future. Consequently, this subcategory is not included in the model plant cost estimates.

The selected model plant sizes, expressed as wastewater flow rate are presented in Table VIII-28.

Cost Effectiveness Summaries

Model plant control cost summary sheets, developed for each model plant to provide a synopsis of the cost analysis and resulting benefits, are provided in Tables VIII-29 through VIII-39. As noted previously, Alternatives R, S, and T in Table VIII-27 are equivalent to Alternatives D, E, and F in Table VIII-1 for existing sources.

NEW INDIRECT DISCHARGE SOURCES

The discussion presented previously for existing indirect discharge sources applies also to new sources. Also, the discussion presented previously about zero discharge, water usage rates, and segregation of waste streams containing toxic pollutants applies equally to both direct and indirect discharge new sources. The benefits of segregation are more evident for indirect sources because the need for biological treatment is eliminated when discharging to a POTW.

In-plant control measures are discussed in Section VII and their importance is emphasized previously in this section. They should be explored fully for new indirect sources to determine whether or not the discharge of toxic pollutants can be controlled adequately to eliminate the need for substantial end-of-pipe treatment facilities.

End-of-Pipe Technologies

Alternatives R, S, and T for new direct discharge sources are modified for new indirect sources by eliminating the activated sludge process and providing segregation of the toxic pollutant waste stream in all cases and for all model plant flows. Screening is provided for all

TABLE VIII-28

SELECTED MODEL PLANT SIZES
NEW SOURCES

Subcategory	Discharge*	Size, mgd Total Q	PPQ**	Q-PPQ
1. Wool Scouring	D	0.25	0.25	-
	I	0.25	0.15	0.10
2. Wool Finishing	D	1.5	1.0	0.50
	I	1.5	1.0	0.50
4. Woven Fabric Finishing				
a. Simple Processing	D	0.60	0.40	0.20
	I	0.25	0.15	0.10
b. Complex Processing	D	3.0	1.8	1.2
	I	0.60	0.40	0.20
c. Complex Processing Plus Desizing	D	1.5	1.0	0.50
	I	1.5	1.0	0.50
5. Knit Fabric Finishing				
a. Simple Processing	D	1.0	0.60	0.40
	I	0.60	0.40	0.20
b. Complex Processing	D	0.60	0.40	0.20
	I	0.60	0.40	0.20
c. Hosiery Products	D	0.11	0.11	-
	I	0.25	0.15	0.10
6. Carpet Finishing	D	0.25	0.25	-
	I	0.60	0.40	0.20
7. Stock & Yarn Finishing	D	0.60	0.40	0.20
	I	0.25	0.15	0.10
8. Nonwoven Manufacturing	D	0.25	0.25	-
	I	0.60	0.40	0.20
9. Felted Fabric Processing	D	0.25	0.25	-
	I	0.25	0.15	0.10

* D refers to direct and I to indirect.
** PPQ - Priority pollutant stream, segregated from other wastewaters.

TABLE VIII-29
MODEL PLANT CONTROL COST SUMMARY - NSPS

SUBCATEGORY: Wool Finishing

CONTROL LEVEL: NSPS

MODEL FLOW: 5,678 (1.5) cu m/day (mgd)

ANNUAL CAPACITY: 6,000 kkg

DAILY CAPACITY: 20 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	15	26	26
Construction	-	60	106	106
Activated Sludge				
Equipment	-	260	23	23
Construction	-	1,040	92	92
Chemical Coagulation				
Equipment	-	50	-	40
Construction	-	200	-	160
Vacuum Filtration				
Equipment	-	20	-	19
Construction	-	38	-	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	52	40	40
Construction	-	208	160	160
Activated Carbon				
Equipment	-	-	415	415
Construction	-	-	415	415
Monitoring	-	15	15	15
Engineering	-	158	111	124
Contingencies	-	294	194	232
Total Investment Costs	-	2,409	1,597	1,901

SUBCATEGORY: Wool Finishing CONTROL LEVEL: NSPS MODEL FLOW: 5,678 (1.5) cu m/day (mgd)

Annual Costs				
Capital	-	241	160	190
Depreciation	-	150	78	99
Useful Life (years)	-	15	19	18
O&M Labor	-	152	120	170
Employees (persons)	-	6.8	5.3	7.5
Maintenance	-	87	41	69
Sludge Disposal	-	4	7	8
Energy & Power	-	35	37	42
Chemicals: Polymer	-	-	-	-
Alum	-	30	-	20
Carbon	-	-	66	66
Monitoring	-	27	27	27
Total Annual Costs	-	726	536	690
Effluent Quality				
		Resulting Mass Loading		
BOD5, kg/day	966	114	284	0-28
COD, kg/day	3,411	738	795	256
TSS, kg/day	341	85	85	85
Phenols, g/day	682	200	57	57
Chromium, g/day	2,842	1,137	1,420	568
		Resulting Concentration		
BOD5, mg/l	170	20	50	0-5
COD, mg/l	600	130	140	45
TSS, mg/l	60	15	15	15
Phenols, ug/l	120	35	10	10
Chromium, ug/l	500	200	250	100

TABLE VIII-30
MODEL PLANT CONTROL COST SUMMARY - NSPS

SUBCATEGORY: Woven Fabric Finishing-Simple Processing

CONTROL LEVEL: NSPS

MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

ANNUAL CAPACITY: 8,700 kkg

DAILY CAPACITY: 29 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	7	20	20
Construction	-	30	78	78
Activated Sludge				
Equipment	-	48	13	13
Construction	-	192	54	54
Chemical Coagulation				
Equipment	-	30	-	23
Construction	-	120	-	92
Vacuum Filtration				
Equipment	-	19	-	19
Construction	-	34	-	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	30	24	24
Construction	-	120	98	98
Activated Carbon				
Equipment	-	-	320	320
Construction	-	-	320	320
Monitoring	-	15	15	15
Engineering	-	59	81	96
Contingencies	-	97	141	167
Total Investment Costs	-	801	1,165	1,372

SUBCATEGORY: Woven Fabric Finishing- Simple Processing   CONTROL LEVEL: NSPS   MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

Annual Costs

Capital	-	80	117	137
Depreciation	-	50	57	67
Useful Life (years)	-	15	19	19
O&M Labor	-	106	77	119
Employees (persons)	-	4.7	5.4	5.3
Maintenance	-	43	21	35
Sludge Disposal	-	8	5	6
Energy & Power	-	20	20	21
Chemicals: Polymer	-	-	-	-
Alum	-	12	-	8
Carbon	-	-	26	26
Monitoring	-	27	27	27
Total Annual Costs	-	346	349	445

Effluent Quality

			Resulting Mass Loading	
BOD5, kg/day	613	16	0-11	0-11
COD, kg/day	2,044	296	114	80
TSS, kg/day	136	23	23	23
Phenols, g/day	114	34	-	-
Chromium, g/day	91	45	23	23

			Resulting Concentration	
BOD5, mg/l	270	7	0-5	0-5
COD, mg/l	900	130	50	35
TSS, mg/l	60	10	10	10
Phenols, ug/l	50	15	-	-
Chromium, ug/l	40	20	10	10

TABLE VIII-31
MODEL PLANT CONTROL COST SUMMARY - NSPS

SUBCATEGORY: Woven Fabric Finishing-Complex Processing CONTROL LEVEL: NSPS MODEL FLOW: 11,355 (3.0) cu m/day (mgd)

ANNUAL CAPACITY: 39,000 kkg DAILY CAPACITY: 130 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	22	41	41
Construction	-	88	162	162
Activated Sludge				
Equipment	-	420	40	40
Construction	-	1,680	160	160
Chemical Coagulation				
Equipment	-	76	-	57
Construction	-	304	-	228
Vacuum Filtration				
Equipment	-	23	-	21
Construction	-	44	-	40
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	82	58	58
Construction	-	328	232	232
Activated Carbon				
Equipment	-	-	590	590
Construction	-	-	590	590
Monitoring	-	15	15	15
Engineering	-	30	152	180
Contingencies	-	462	283	335
Total Investment Costs	-	3,775	2,323	2,749

SUBCATEGORY: Woven Fabric Finishing-Complex Processing

CONTROL LEVEL: NSPS

MODEL FLOW: 11,355 (3.0) cu m/day (mgd)

Annual Costs

Capital	-	378	232	275
Depreciation	-	236	114	143
Useful Life (years)	-	15	19	18
O&M Labor	-	209	167	225
Employees (persons)	-	9.3	7.4	10
Maintenance	-	152	679	116
Sludge Disposal	-	6	3	4
Energy & Power	-	55	64	73
Chemicals: Polymer	-	-	-	-
Alum	-	60	-	35
Carbon	-	-	117	117
Monitoring	-	27	27	27
Total Annual Costs	-	1,122	793	1,015

Effluent Quality

Resulting Mass Loading

BOD_5, kg/day	3,974	114	0-57	0-57
COD, kg/day	12,491	1,590	568	398
TSS, kg/day	1,249	170	170	170
Phenols, g/day	568	341	114	114
Chromium, g/day	1,249	341	170	170

Resulting Concentration

BOD_5, mg/l	350	10	0-5	0-5
COD, mg/l	1,100	140	50	35
TSS, mg/l	110	15	15	15
Phenols, ug/l	50	30	10	10
Chromium, ug/l	110	30	15	15

TABLE VIII-32
MODEL PLANT CONTROL COST SUMMARY - NSPS

SUBCATEGORY: Woven Fabric Finishing-
Complex Processing Plus Designing

CONTROL LEVEL: NSPS

MODEL FLOW: 5,678 (1.5) cu m/day (mgd)

ANNUAL CAPACITY: 15,000 kkg

DAILY CAPACITY: 50 kkg

	Treatment Alternative			
	A	R	S	T
Investment Costs	Cost, thousands of dollars			
Preliminary Treatment				
Equipment	-	15	26	26
Construction	-	60	106	106
Activated Sludge				
Equipment	-	260	23	23
Construction	-	1,040	92	92
Chemical Coagulation				
Equipment	-	50	-	40
Construction	-	200	-	160
Vacuum Filtration				
Equipment	-	19	-	20
Construction	-	34	-	37
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	52	40	40
Construction	-	208	160	160
Activated Carbon				
Equipment	-	-	415	415
Construction	-	-	415	415
Monitoring	-	27	27	27
Engineering	-	157	111	125
Contingencies	-	293	194	232
Total Investment Costs	-	2,403	1,597	1,906

SUBCATEGORY: Woven Fabric Finishing- Complex Processing Plus Designing CONTROL LEVEL: NSPS MODEL FLOW: 5,678 (1.5) cu m/day (mgd)

Annual Costs

Capital	-	240	160	191
Depreciation	-	150	78	99
Useful Life (years)	-	15	19	18
O&M Labor	-	152	120	170
Employees (persons)	-	6.8	5.3	7.5
Maintenance	-	87	41	69
Sludge Disposal	-	3	7	4
Energy & Power	-	35	37	42
Chemicals: Polymer	-	-	-	-
Alum	-	30	-	20
Carbon	-	-	66	66
Monitoring	-	27	27	27
Total Annual Costs	-	759	536	688

Effluent Quality

			Resulting Mass Loading	
BOD_5, kg/day	2,388	57	0-28	0-28
COD, kg/day	7,049	795	284	199
TSS, kg/day	853	85	85	85
Phenols, g/day	853	142	28	28
Chromium, g/day	568	170	85	85

			Resulting Concentration	
BOD_5, mg/l	420	10	0-5	0-5
COD, mg/l	1,240	140	50	35
TSS, mg/l	150	15	15	15
Phenols, ug/l	150	25	5	5
Chromium, ug/l	100	30	15	15

TABLE VIII-33
MODEL PLANT CONTROL COST SUMMARY - NSPS

SUBCATEGORY: Knit Fabric Finishing-Simple Processing

CONTROL LEVEL: NSPS

MODEL FLOW: 3,785 (1.0) cu m/day (mgd)

ANNUAL CAPACITY: 9,300 kkg

DAILY CAPACITY: 31 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	10	22	22
Construction	-	40	99	99
Activated Sludge				
Equipment	-	200	20	20
Construction	-	800	80	80
Chemical Coagulation				
Equipment	-	40	-	30
Construction	-	160	-	120
Vacuum Filtration				
Equipment	-	19	-	19
Construction	-	34	-	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	40	30	30
Construction	-	160	120	120
Activated Carbon				
Equipment	-	-	340	340
Construction	-	-	340	340
Monitoring	-	15	15	15
Engineering	-	122	91	109
Contingencies	-	228	158	189
Total Investment Costs	-	1,868	1,305	1,556

SUBCATEGORY: Knit Fabric Finishing-
Simple Processing

CONTROL LEVEL: NSPS

MODEL FLOW: 3,785 (1.0) cu m/day (mgd)

Annual Costs				
Capital	-	187	131	156
Depreciation	-	116	64	80
Useful Life (years)	-	15	19	18
O&M Labor	-	129	99	144
Employees (persons)	-	5.7	4.4	6.4
Maintenance	-	63	29	48
Sludge Disposal	-	6	6	7
Energy & Power	-	27	27	33
Chemicals: Polymer	-	-	-	-
Alum	-	20	-	12
Carbon	-	-	40	40
Monitoring	-	27	27	27
Total Annual Costs	-	576	422	547
Effluent Quality				
		Resulting Mass Loading		
BOD_5, kg/day	796	19	0-19	0-19
COD, kg/day	3,297	568	227	152
TSS, kg/day	190	38	38	38
Phenols, g/day	417	95	19	19
Chromium, g/day	303	227	114	114
		Resulting Concentration		
BOD_5, mg/l	210	5	0-5	0-5
COD, mg/l	870	150	60	40
TSS, mg/l	50	10	10	10
Phenols, ug/l	110	25	5	5
Chromium, ug/l	80	60	30	30

TABLE VIII-34
MODEL PLANT CONTROL COST SUMMARY - NSPS

SUBCATEGORY: Knit Fabric Finishing-Complex Processing

CONTROL LEVEL: NSPS

MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

ANNUAL CAPACITY: 5,600 kkg

DAILY CAPACITY: 18.6 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	7	20	20
Construction	-	30	78	78
Activated Sludge				
Equipment	-	48	13	13
Construction	-	192	54	54
Chemical Coagulation				
Equipment	-	30	-	23
Construction	-	120	-	92
Vacuum Filtration				
Equipment	-	19	-	19
Construction	-	34	-	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	30	24	24
Construction	-	120	98	98
Activated Carbon				
Equipment	-	-	320	320
Construction	-	-	320	320
Monitoring	-	15	15	15
Engineering	-	59	81	96
Contingencies	-	97	141	167
Total Investment Costs	-	801	1,165	1,372

SUBCATEGORY: Knit Fabric Finishing-Complex Processing CONTROL LEVEL: NSPS MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

Annual Costs				
Capital	-	80	117	137
Depreciation	-	50	57	67
Useful Life (years)	-	15	19	19
O&M Labor	-	106	77	119
Employees (persons)	-	4.7	-	-
Maintenance	-	43	21	35
Sludge Disposal	-	7	5	6
Energy & Power	-	20	20	21
Chemicals: Polymer	-	-	-	-
Alum	-	12	-	8
Carbon	-	-	26	26
Monitoring	-	27	27	27
Total Annual Costs	-	345	349	445
Effluent Quality				
		Resulting Mass Loading		
BOD5, kg/day	614	23	0-11	0-11
COD, kg/day	1,796	341	125	79
TSS, kg/day	136	23	23	23
Phenols, g/day	227	68	11	11
Chromium, g/day	182	57	23	23
		Resulting Concentration		
BOD5, mg/l	270	10	0-5	0-5
COD, mg/l	790	150	55	35
TSS, mg/l	60	10	10	10
Phenols, ug/l	100	30	5	5
Chromium, ug/l	80	25	10	10

TABLE VIII-35
MODEL PLANT CONTROL COST SUMMARY - NSPS

SUBCATEGORY: Knit Fabric Finishing-Hosiery Products   CONTROL LEVEL: NSPS   MODEL FLOW: 416 (0.11) cu m/day (mgd)

ANNUAL CAPACITY: 1,800 kkg   DAILY CAPACITY: 6 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	5		5
Construction	-	21	No	21
Activated Sludge			Alternative	
Equipment	-	18	S for	18
Construction	-	72	this	72
Chemical Coagulation			Subcategory	
Equipment	-	11		11
Construction	-	43		43
Vacuum Filtration				
Equipment	-	19		19
Construction	-	34		34
Dissolved Air Flotation				
Equipment	-	-		-
Construction	-	-		-
Multi-Media Filtration				
Equipment	-	12		12
Construction	-	47		47
Activated Carbon				
Equipment	-	-		300
Construction	-	-		300
Monitoring	-	27		27
Engineering	-	32		38
Contingencies	-	45		54
Total Investment Costs	-	374		454

SUBCATEGORY: Knit Fabric Finishing-Hosiery Products CONTROL LEVEL: NSPS MODEL FLOW: 416 (0.11) cu m/day (mgd)

Annual Costs

Capital	-	37	45
Depreciation	-	23	26
Useful Life (years)	-	15	16
O&M Labor	-	64	65
Employees (persons)	-	2.8	-
Maintenance	-	13	15
Sludge Disposal	-	4	5
Energy & Power	-	8	8
Chemicals: Polymer	-	-	-
Alum	-	2	2
Carbon	-	-	91
Monitoring	-	27	27
Total Annual Costs	-	179	284

Effluent Quality

			Resulting Mass Loading
BOD5, kg/day	133	12	0-2
COD, kg/day	570	129	21
TSS, kg/day	33	4	4
Phenols, g/day	25	12	2
Chromium, g/day	33	12	6

			Resulting Concentration
BOD5, mg/l	320	30	0-5
COD, mg/l	1,370	310	50
TSS, mg/l	80	10	10
Phenols, ug/l	60	30	5
Chromium, ug/l	80	30	15

TABLE VIII-36
MODEL PLANT CONTROL COST SUMMARY - NSPS

SUBCATEGORY: Carpet Finishing CONTROL LEVEL: NSPS MODEL FLOW: 946 (0.25) cu m/day (mgd)

ANNUAL CAPACITY: 6,100 kkg DAILY CAPACITY: 20 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	6	6	6
Construction	-	24	24	24
Activated Sludge				
Equipment	-	29	29	29
Construction	-	116	116	116
Chemical Coagulation				
Equipment	-	18	-	18
Construction	-	70	-	70
Vacuum Filtration				
Equipment	-	19	-	19
Construction	-	34	-	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	19	19	19
Construction	-	77	77	77
Activated Carbon				
Equipment	-	-	300	300
Construction	-	-	300	300
Monitoring	-	27	27	27
Engineering	-	42	76	89
Contingencies	-	64	133	154
Total Investment Costs	-	532	1,095	1,270

SUBCATEGORY: Carpet Finishing CONTROL LEVEL: NSPS MODEL FLOW: 946 (0.25) cu m/day (mgd)

Annual Costs

Capital	-	53	110	127
Depreciation	-	33	57	66
Useful Life (years)	-	15	18	18
O&M Labor	-	77	48	87
Employees (persons)	-	3.4	2.1	3.9
Maintenance	-	23	16	26
Sludge Disposal	-	5	4	5
Energy & Power	-	12	16	17
Chemicals: Polymer	-	-	-	-
Alum	-	5	-	5
Carbon	-	-	17	17
Monitoring	-	27	27	27
Total Annual Costs	-	235	293	376

Effluent Quality

		Resulting Mass Loading		
BOD5, kg/day	416	14	0-5	0-5
COD, kg/day	1,126	151	52	38
TSS, kg/day	66	9	9	9
Phenols, g/day	123	43	9	9
Chromium, g/day	28	24	9	9

		Resulting Concentration		
BOD5, mg/l	440	15	0-5	0-5
COD, mg/l	1,190	160	55	40
TSS, mg/l	70	10	10	10
Phenols, ug/l	130	45	10	10
Chromium, ug/l	30	25	10	10

TABLE VIII-37
MODEL PLANT CONTROL COST SUMMARY - NSPS

SUBCATEGORY: Stock & Yarn Finishing   CONTROL LEVEL: NSPS   MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

ANNUAL CAPACITY: 6,800 kkg   DAILY CAPACITY: 23 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	7	20	20
Construction	-	30	78	78
Activated Sludge				
Equipment	-	48	13	13
Construction	-	192	54	54
Chemical Coagulation				
Equipment	-	30	-	23
Construction	-	120	-	92
Vacuum Filtration				
Equipment	-	19	-	19
Construction	-	34	-	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	30	24	24
Construction	-	120	98	98
Activated Carbon				
Equipment	-	-	320	320
Construction	-	-	320	320
Monitoring	-	27	27	27
Engineering	-	59	81	96
Contingencies	-	97	141	167
Total Investment Costs	-	801	1,165	1,372

SUBCATEGORY: Stock & Yarn Finishing CONTROL LEVEL: NSPS MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

<u>Annual Costs</u>

Capital		-	80	117	137
Depreciation		-	50	57	67
Useful Life (years)		-	15	19	19
O&M Labor		-	106	77	119
Employees (persons)		-	4.7	3.1	4.9
Maintenance		-	43	21	35
Sludge Disposal		-	8	5	5
Energy & Power		-	20	20	21
Chemicals:	Polymer	-	-	-	-
	Alum	-	12	-	8
	Carbon	-	-	26	26
Monitoring		-	27	27	27
Total Annual Costs		-	346	349	445

<u>Effluent Quality</u>

		Resulting Mass Loading		
BOD_5, kg/day	409	11	0-11	0-11
COD, kg/day	1,546	182	68	45
TSS, kg/day	91	11	11	11
Phenols, g/day	386	68	11	11
Chromium, g/day	227	91	45	45

		Resulting Concentration		
BOD_5, mg/l	180	5	0-5	0-5
COD, mg/l	680	80	30	20
TSS, mg/l	40	5	5	5
Phenols, ug/l	170	30	5	5
Chromium, ug/l	100	40	20	20

TABLE VIII-38
MODEL PLANT CONTROL COST SUMMARY - NSPS

SUBCATEGORY: Nonwoven Manufacturing CONTROL LEVEL: NSPS MODEL FLOW: 416 (0.21) cu m/day (mgd)

ANNUAL CAPACITY: 3,120 kkg DAILY CAPACITY: 10.4 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	6	6	6
Construction	-	24	24	24
Activated Sludge				
Equipment	-	29	29	29
Construction	-	116	116	116
Chemical Coagulation				
Equipment	-	18	-	18
Construction	-	70	-	70
Vacuum Filtration				
Equipment	-	19	-	19
Construction	-	34	-	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	19	19	19
Construction	-	77	77	77
Activated Carbon				
Equipment	-	-	300	300
Construction	-	-	300	300
Monitoring	-	27	27	27
Engineering	-	42	76	89
Contingencies	-	64	133	154
Total Investment Costs	-	532	1,095	1,270

SUBCATEGORY: Nonwoven Manufacturing   CONTROL LEVEL: NSPS   MODEL FLOW: 416 (0.11) cu m/day (mgd)

Annual Costs

Capital	-	53	110	127
Depreciation	-	33	57	66
Useful Life (years)	-	15	18	18
O&M Labor	-	77	48	87
Employees (persons)	-	3.4	2.1	3.9
Maintenance	-	23	16	26
Sludge Disposal	-	5	4	5
Energy & Power	-	12	16	17
Chemicals: Polymer	-	-	-	-
Alum	-	5	-	5
Carbon	-	-	17	17
Monitoring	-	27	27	27
Total Annual Costs	-	235	293	376

Effluent Quality

		Resulting Mass Loading		
BOD5, kg/day	75	6	23	4
COD, kg/day	982	129	241	25
TSS, kg/day	33	4	4	4
Phenols, g/day	17	8	2	2
Chromium, g/day	4	4	2	2

		Resulting Concentration		
BOD5, mg/l	180	15	55	10
COD, mg/l	2,360	310	580	60
TSS, mg/l	80	10	10	10
Phenols, ug/l	40	20	5	5
Chromium, ug/l	10	10	5	5

TABLE VIII-39
MODEL PLANT CONTROL COST SUMMARY - NSPS

SUBCATEGORY: Felted Fabric Processing CONTROL LEVEL: NSPS MODEL FLOW: 416 (0.11) cu m/day (mgd)

ANNUAL CAPACITY: 585 kkg DAILY CAPACITY: 2 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	6	6	6
Construction	-	24	24	24
Activated Sludge				
Equipment	-	29	29	29
Construction	-	116	116	116
Chemical Coagulation				
Equipment	-	18	-	18
Construction	-	70	-	70
Vacuum Filtration				
Equipment	-	19	-	19
Construction	-	34	-	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	19	19	19
Construction	-	77	77	77
Activated Carbon				
Equipment	-	-	300	300
Construction	-	-	300	300
Monitoring	-	27	27	27
Engineering	-	42	76	89
Contingencies	-	64	133	154
Total Investment Costs	-	532	1,095	1,270

SUBCATEGORY: Felted Fabric Processing   CONTROL LEVEL: NSPS   MODEL FLOW: 416 (0.11) cu m/day (mgd)

Annual Costs				
Capital	-	53	110	127
Depreciation	-	33	57	66
Useful Life (years)	-	15	18	18
O&M Labor	-	77	48	87
Employees (persons)	-	3.4	2.1	3.9
Maintenance	-	23	16	26
Sludge Disposal	-	5	4	5
Energy & Power	-	12	16	17
Chemicals: Polymer	-	-	-	-
Alum	-	5	-	5
Carbon	-	-	17	17
Monitoring	-	27	27	27
Total Annual Costs	-	235	293	376
Effluent Quality				
		Resulting Mass Loading		
BOD5, kg/day	83	6	25	4
COD, kg/day	229	71	50	21
TSS, kg/day	50	4	4	4
Phenols, g/day	241	15	25	25
Chromium, g/day	-	-	-	-
		Resulting Concentration		
BOD5, mg/l	200	15	60	10
COD, mg/l	550	170	120	50
TSS, mg/l	120	10	10	10
Phenols, ug/l	580	35	60	60
Chromium, ug/l	-	-	-	-

wastes prior to discharge and equalization is provided for the toxic pollutant stream prior to any advanced treatment processes. The alternatives are described briefly in Table VIII-40.

The criteria used in sizing the various processes for Alternatives R, S, and T are discussed under existing sources.

Investment Costs and Annual Costs

The bases used for estimating investment costs for new indirect discharge sources were the same as those for existing sources and are discussed previously in this section. The cost curves in Figures VIII-1 through VIII-8 apply for new indirect discharge sources.

Land Costs

Without activated sludge facilities, the land requirements for new indirect discharge sources will be considerably smaller than for new direct discharge sources, i.e., less than 1 hectare (2.5 acres) for the largest flows.

Model Plant Costs

The model plant sizes selected for new indirect discharge sources are given in Table VIII-28.

Cost Effectiveness Summaries

Tables VIII-41 through VIII-51 provide synopses of the elements in the estimated costs and the expected resultant benefits for the model plants selected to represent new indirect discharge sources in each subcategory.

ENERGY ASPECTS

An analysis was carried out to estimate the energy requirements of the end-of-pipe treatment alternatives in terms of reported total mill energy usage for selected subcategories. The annual energy requirements for each treatment alternative were derived in order to estimate the cost for electrical power for the various equipment components. For each of the selected subcategories, the estimated energy requirements were expressed in terms of annual production for the model plant sizes. From the detailed questionnaires, the reported total mill energy consumption as electric power, oil, and gas was calculated in common units and expressed in terms of annual production. The median value for the mills in each subcategory, combining both direct and indirect dischargers, was then used as the base value for that subcategory. The median total mill energy

TABLE VIII-40

ALTERNATIVE END-OF-PIPE TREATMENT TECHNOLOGIES
NEW SOURCES - INDIRECT DISCHARGE

Technology	Description
A	No treatment
R	Priority pollutant stream - Screening, equalization, chemical coagulation, sedimentation, and multi-media filtration. Other streams - Screening.
S	Priority pollutant stream - Screening, equalization, multi-media filtration, and granular activated carbon adsorption. Other streams - Screening.
T	Priority pollutant stream - Screening, equalization, chemical coagulation, sedimentation, multi-media filtration, and granular activated carbon adsorption. Other streams - Screening.

TABLE VIII-41
MODEL PLANT CONTROL COST SUMMARY - PSNS

SUBCATEGORY: Wool Finishing | CONTROL LEVEL: PSNS | MODEL FLOW: 5,678 (1.5) cu m/day (mgd)

ANNUAL CAPACITY: 600 kkg | DAILY CAPACITY: 20 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	26	26	26
Construction	-	106	106	106
Activated Sludge				
Equipment	-	-	-	-
Construction	-	-	-	-
Chemical Coagulation				
Equipment	-	40	-	40
Construction	-	160	-	160
Vacuum Filtration				
Equipment	-	19	19	19
Construction	-	34	34	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	40	40	40
Construction	-	160	160	160
Activated Carbon				
Equipment	-	-	415	415
Construction	-	-	415	415
Monitoring	-	15	15	115
Engineering	-	55	106	115
Contingencies	-	90	185	215
Total Investment Costs	-	745	1521	1760

SUBCATEGORY: Wool Finishing CONTROL LEVEL: PSNS MODEL FLOW: 5,678 (1.5) cu m/day (mgd)

Annual Costs

Capital	-	75	152	176
Depreciation	-	43	75	86
Useful Life (years)	-	16	19	19
O&M Labor	-	111	130	139
Employees (persons)	-	4.9	5.8	6.2
Maintenance	-	50	43	61
Sludge Disposal	-	7	6	8
Energy & Power	-	7	24	28
Chemicals: Polymer	-	-	-	-
Alum	-	20	-	20
Carbon	-	-	66	66
Monitoring	-	13	13	13
Total Annual Costs	-	327	507	596

Effluent Quality

Resulting Mass Loading

BOD5, kg/day	966	170	285	57
COD, kg/day	3411	1308	197	341
TSS, kg/day	341	57	57	57
Phenols, g/day	682	682	57	57
Chromium, g/day	2842	2842	1421	1421

Resulting Concentration

BOD5, mg/l	170	30	50	10
COD, mg/l	600	230	140	60
TSS, mg/l	60	10	10	10
Phenols, ug/l	120	120	10	10
Chromium, ug/l	500	500	250	500

TABLE VIII-42
MODEL PLANT CONTROL COST SUMMARY - PSNS

SUBCATEGORY: Woven Fabric Finishing - Simple Processing   CONTROL LEVEL: PSNS   MODEL FLOW: 946 (0.25) cu m/day (mgd)

ANNUAL CAPACITY: 3,600 kkg   DAILY CAPACITY: 12 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	16	16	16
Construction	-	65	65	65
Activated Sludge				
Equipment	-	-	-	-
Construction	-	-	-	-
Chemical Coagulation				
Equipment	-	13	-	13
Construction	-	52	-	52
Vacuum Filtration				
Equipment	-	19	19	19
Construction	-	34	34	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	14	14	14
Construction	-	56	56	56
Activated Carbon				
Equipment	-	-	280	280
Construction	-	-	280	280
Monitoring	-	15	15	15
Engineering	-	31	67	73
Contingencies	-	43	117	127
Total Investment Costs	-	358	963	1043

SUBCATEGORY: Woven Fabric Finishing - Simple Processing   CONTROL LEVEL: PSNS   MODEL FLOW: 946 (0.25) cu m/day (mgd)

Annual Costs				
Capital	-	36	96	104
Depreciation	-	19	47	51
Useful Life (years)	-	17	19	19
O&M Labor	-	69	72	76
Employees (persons)	-	3.1	3.2	3.4
Maintenance	-	13	12	15
Sludge Disposal	-	2	2	2
Energy & Power	-	2	4	5
Chemicals: Polymer	-	-	-	-
Alum	-	3	-	3
Carbon	-	-	10	10
Monitoring	-	13	13	13
Total Annual Costs	-	156	257	279
Effluent Quality				
				Resulting Mass Loading
BOD5, kg/day	255	38	85	14
COD, kg/day	853	256	207	66
TSS, kg/day	57	9	10	9
Phenols, g/day	47	41	5	5
Chromium, g/day	38	38	19	19
				Resulting Concentration
BOD5, mg/l	270	40	90	15
COD, mg/l	900	270	220	70
TSS, mg/l	60	10	10	10
Phenols, ug/l	50	50	5	5
Chromium, ug/l	40	40	20	20

TABLE VIII-43
MODEL PLANT CONTROL COST SUMMARY - PSNS

SUBCATEGORY: Woven Fabric Finishing - Complex Processing CONTROL LEVEL: PSNS MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

ANNUAL CAPACITY: 7,900 kkg DAILY CAPACITY: 26 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	20	20	20
Construction	-	78	78	78
Activated Sludge				
Equipment	-	-	-	-
Construction	-	-	-	-
Chemical Coagulation				
Equipment	-	23	-	23
Construction	-	92	-	92
Vacuum Filtration				
Equipment	-	19	19	19
Construction	-	34	34	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	24	24	24
Construction	-	98	98	98
Activated Carbon				
Equipment	-	-	320	320
Construction	-	-	320	320
Monitoring	-	15	15	15
Engineering	-	39	80	90
Contingencies	-	61	139	157
Total Investment Costs	-	503	1147	1289

SUBCATEGORY: Woven Fabric Finishing - Complex Processing CONTROL LEVEL: PSNS MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

Annual Costs

Capital	-	50	115	129
Depreciation	-	27	56	63
Useful Life (years)	-	17	19	19
O&M Labor	-	85	93	99
Employees (persons)	-	3.8	4.1	4.4
Maintenance	-	26	23	31
Sludge Disposal	-	4	4	5
Energy & Power	-	3	10	11
Chemicals: Polymer	-	-	-	-
Alum	-	8	-	8
Carbon	-	-	26	26
Monitoring	-	13	13	13
Total Annual Costs	-	217	340	351

Effluent Quality

			Resulting Mass Loading	
BOD5, kg/day	796	91	0-11	34
COD, kg/day	2501	614	114	159
TSS, kg/day	250	23	23	23
Phenols, g/day	114	114	23	11
Chromium, g/day	250	250	34	125
			Resulting Concentration	
BOD5, mg/l	350	40	0-5	15
COD, mg/l	1100	270	50	70
TSS, mg/l	110	10	10	10
Phenols, ug/l	50	50	10	5
Chromium, ug/l	110	110	15	55

TABLE VIII-44
MODEL PLANT CONTROL COST SUMMARY - PSNS

SUBCATEGORY: Woven Fabric Finishing- Complex Processing Plus Desizing   CONTROL LEVEL: PSNS   MODEL FLOW: 5,678 (1.5) cu m/day (mgd)

ANNUAL CAPACITY: 1,500 kkg   DAILY CAPACITY: 50 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	26	26	26
Construction	-	106	106	106
Activated Sludge				
Equipment	-	-	-	-
Construction	-	-	-	-
Chemical Coagulation				
Equipment	-	40	-	40
Construction	-	160	-	160
Vacuum Filtration				
Equipment	-	19	19	20
Construction	-	34	34	37
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	40	40	40
Construction	-	160	160	160
Activated Carbon				
Equipment	-	-	415	415
Construction	-	-	415	415
Monitoring	-	15	15	15
Engineering	-	56	106	115
Contingencies	-	91	185	215
Total Investment Costs	-	750	1521	1765

SUBCATEGORY: Woven Fabric Finishing- Complex Processing Plus Desizing   CONTROL LEVEL: PSNS   MODEL FLOW: 5,678 (1.5) cu m/day (mgd)

<u>Annual Costs</u>

Capital	-	75	152	1765
Depreciation	-	43	75	87
Useful Life (years)	-	16	19	19
O&M Labor	-	111	130	139
Employees (persons)	-	4.9	5.8	5.6
Maintenance	-	50	43	61
Sludge Disposal	-	8	6	8
Energy & Power	-	7	24	28
Chemicals: Polymer	-	-	-	-
Alum	-	20	-	20
Carbon	-	-	66	66
Monitoring	-	13	13	13
Total Annual Costs	-	328	507	598

<u>Effluent Quality</u>

				Resulting Mass Loading
BOD5, kg/day	2388	170	0-28	57
COD, kg/day	7049	796	284	199
TSS, kg/day	853	57	57	57
Phenols, g/day	853	853	28	85
Chromium, g/day	568	568	85	284

				Resulting Concentration
BOD5, mg/l	420	30	0-5	10
COD, mg/l	1240	140	50	35
TSS, mg/l	150	10	10	10
Phenols, ug/l	150	150	5	15
Chromium, ug/l	100	100	15	50

TABLE VIII-45
MODEL PLANT CONTROL COST SUMMARY - PSNS

SUBCATEGORY: Knit Fabric Finishing-Simple Processing   CONTROL LEVEL: PSNS   MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

ANNUAL CAPACITY: 5,600 kkg   DAILY CAPACITY: 18.6 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	20	20	20
Construction	-	78	80	78
Activated Sludge				
Equipment	-	-	-	-
Construction	-	-	-	-
Chemical Coagulation				
Equipment	-	23	-	23
Construction	-	92	-	92
Vacuum Filtration				
Equipment	-	19	19	19
Construction	-	34	34	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	24	24	24
Construction	-	98	98	98
Activated Carbon				
Equipment	-	-	320	320
Construction	-	-	320	320
Monitoring	-	15	15	15
Engineering	-	39	80	90
Contingencies	-	61	139	157
Total Investment Costs	-	503	1147	1289

SUBCATEGORY: Knit Fabric Finishing-Simple Processing

CONTROL LEVEL: PSNS

MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

Annual Costs				
Capital	-	50	115	129
Depreciation	-	27	56	63
Useful Life (years)	-	17	19	19
O&M Labor	-	85	93	99
Employees (persons)	-	3.8	4.1	4.4
Maintenance	-	26	23	31
Sludge Disposal	-	4	4	4
Energy & Power	-	3	10	11
Chemicals: Polymer	-	-	-	-
Alum	-	8	-	8
Carbon	-	-	26	26
Monitoring	-	13	13	13
Total Annual Costs	-	216	340	381
Effluent Quality			Resulting Mass Loading	
BOD5, kg/day	478	91	159	34
COD, kg/day	1978	591	477	148
TSS, kg/day	114	23	23	23
Phenols, g/day	250	250	23	23
Chromium, g/day	182	182	91	91
			Resulting Concentration	
BOD5, mg/l	210	40	70	15
COD, mg/l	870	260	210	65
TSS, mg/l	50	10	10	10
Phenols, ug/l	110	110	10	10
Chromium, ug/l	80	80	40	40

TABLE VIII-46
MODEL PLANT CONTROL COST SUMMARY - PSNS

SUBCATEGORY: Knit Fabric Finishing-Complex Processing

CONTROL LEVEL: PSNS

MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

ANNUAL CAPACITY: 5,600 kkg

DAILY CAPACITY: 18.6 kkg

	Treatment Alternative			
	A	R	S	T
Investment Costs	Cost, thousands of dollars			
Preliminary Treatment				
Equipment	-	20	20	20
Construction	-	78	78	78
Activated Sludge				
Equipment	-	-	-	-
Construction	-	-	-	-
Chemical Coagulation				
Equipment	-	23	-	23
Construction	-	92	-	92
Vacuum Filtration				
Equipment	-	19	19	19
Construction	-	34	34	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	24	24	24
Construction	-	98	98	98
Activated Carbon				
Equipment	-	-	320	320
Construction	-	-	320	320
Monitoring	-	15	15	15
Engineering	-	39	80	90
Contingencies	-	60	139	157
Total Investment Costs	-	503	1147	1289

SUBCATEGORY: Knit Fabric Finishing-Complex Processing CONTROL LEVEL: PSNS MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

Annual Costs				
Capital	-	50	115	129
Depreciation	-	27	56	63
Useful Life (years)	-	17	19	19
O&M Labor	-	85	93	99
Employees (persons)	-	3.8	4.1	4.4
Maintenance	-	26	23	31
Sludge Disposal	-	5	4	5
Energy & Power	-	3	10	11
Chemicals: Polymer	-	-	-	-
Alum	-	8	-	8
Carbon	-	-	26	26
Monitoring	-	13	13	13
Total Annual Costs	-	217	340	351
Effluent Quality				
				Resulting Mass Loading
BOD5, kg/day	614	91	204	34
COD, kg/day	1796	591	431	148
TSS, kg/day	136	23	23	23
Phenols, g/day	227	227	23	23
Chromium, g/day	182	182	91	91
				Resulting Concentration
BOD5, mg/l	270	40	90	15
COD, mg/l	790	260	190	65
TSS, mg/l	60	10	10	10
Phenols, ug/l	100	100	10	10
Chromium, ug/l	80	80	40	40

TABLE VIII-47

MODEL PLANT CONTROL COST SUMMARY - PSNS

SUBCATEGORY: Knit Fabric Finishing-Hosiery Products   CONTROL LEVEL: PSNS   MODEL FLOW: 946 (0.25) cu m/day (mgd)

ANNUAL CAPACITY: 4,100 kkg   DAILY CAPACITY: 13.6 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	16	16	16
Construction	-	65	65	65
Activated Sludge				
Equipment	-	-	-	-
Construction	-	-	-	-
Chemical Coagulation				
Equipment	-	13	-	13
Construction	-	52	-	52
Vacuum Filtration				
Equipment	-	19	19	19
Construction	-	34	34	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	14	14	14
Construction	-	56	56	56
Activated Carbon				
Equipment	-	-	280	280
Construction	-	-	280	280
Monitoring	-	15	15	15
Engineering	-	31	67	73
Contingencies	-	43	117	127
Total Investment Costs	-	358	963	1043

SUBCATEGORY: Knit Fabric Finishing- Hosiery Products   CONTROL LEVEL: PSNS   MODEL FLOW: 946 (0.25) cu m/day (mgd)

Annual Costs				
Capital	-	36	96	104
Depreciation	-	19	47	51
Useful Life (years)	-	17	19	19
O&M Labor	-	68	72	76
Employees (persons)	-	3.0	3.2	3.4
Maintenance	-	13	12	15
Sludge Disposal	-	3	2	3
Energy & Power	-	2	4	5
Chemicals: Polymer	-	-	-	-
Alum	-	3	-	3
Carbon	-	-	10	10
Monitoring	-	13	13	13
Total Annual Costs	-	150	257	279
Effluent Quality				
				Resulting Mass Loading
BOD_5, kg/day	303	47	95	19
COD, kg/day	1298	265	314	66
TSS, kg/day	76	9	10	9
Phenols, g/day	57	57	5	5
Chromium, g/day	76	76	38	38
				Resulting Concentration
BOD_5, mg/l	320	50	100	20
COD, mg/l	1370	280	330	70
TSS, mg/l	80	10	10	10
Phenols, ug/l	60	60	5	5
Chromium, ug/l	80	80	40	40

TABLE VIII-48
MODEL PLANT CONTROL COST SUMMARY - PSNS

SUBCATEGORY: Carpet Finishing   CONTROL LEVEL: PSNS   MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

ANNUAL CAPACITY: 14,600 kkg   DAILY CAPACITY: 49 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	20	20	20
Construction	-	80	80	78
Activated Sludge				
Equipment	-	-	-	-
Construction	-	-	-	-
Chemical Coagulation				
Equipment	-	23	-	23
Construction	-	92	-	92
Vacuum Filtration				
Equipment	-	19	19	19
Construction	-	34	34	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	24	24	24
Construction	-	98	98	98
Activated Carbon				
Equipment	-	-	320	320
Construction	-	-	320	320
Monitoring	-	15	15	15
Engineering	-	40	80	90
Contingencies	-	61	139	157
Total Investment Costs	-	503	1147	1289

SUBCATEGORY: Carpet Finishing CONTROL LEVEL: PSNS MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

Annual Costs				
Capital	-	50	115	129
Depreciation	-	27	56	63
Useful Life (years)	-	17	19	19
O&M Labor	-	85	93	99
Employees (persons)	-	3.8	4.1	3.5
Maintenance	-	26	23	31
Sludge Disposal	-	5	4	5
Energy & Power	-	3	10	11
Chemicals: Polymer	-	-	-	-
Alum	-	8	-	-
Carbon	-	-	26	-
Monitoring	-	13	13	13
Total Annual Costs	-	217	340	351
Effluent Quality				
		Resulting Mass Loading		
BOD5, kg/day	1000	57	341	23
COD, kg/day	2706	364	658	91
TSS, kg/day	159	23	23	23
Phenols, g/day	296	296	34	34
Chromium, g/day	68	68	34	34
		Resulting Concentration		
BOD5, mg/l	440	25	150	10
COD, mg/l	1190	160	290	40
TSS, mg/l	70	10	10	10
Phenols, ug/l	130	30	15	15
Chromium, ug/l	30	30	15	15

TABLE VIII-49
MODEL PLANT CONTROL COST SUMMARY - PSNS

SUBCATEGORY: Stock & Yarn Finishing   CONTROL LEVEL: PSNS   MODEL FLOW: 946 (0.25) cu m/day (mgd)

ANNUAL CAPACITY: 2,800 kkg   DAILY CAPACITY: 9.4 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	16	16	16
Construction	-	65	65	65
Activated Sludge				
Equipment	-	-	-	-
Construction	-	-	-	-
Chemical Coagulation				
Equipment	-	13	-	13
Construction	-	52	-	52
Vacuum Filtration				
Equipment	-	19	19	19
Construction	-	34	34	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	14	14	14
Construction	-	56	56	56
Activated Carbon				
Equipment	-	-	280	280
Construction	-	-	280	280
Monitoring	-	15	15	15
Engineering	-	31	67	73
Contingencies	-	43	117	127
Total Investment Costs	-	358	963	1043

SUBCATEGORY: Stock & Yarn Finishing CONTROL LEVEL: PSNS MODEL FLOW: 946 (0.25) cu m/day (mgd)

<u>Annual Costs</u>

Capital	-	36	96	104
Depreciation	-	19	47	51
Useful Life (years)	-	17	19	19
O&M Labor	-	68	72	76
Employees (persons)	-	3.0	3.2	3.4
Maintenance	-	13	12	15
Sludge Disposal	-	2	2	2
Energy & Power	-	2	4	5
Chemicals: Polymer	-	-	-	-
Alum	-	3	-	3
Carbon	-	-	10	10
Monitoring	-	27	13	13
Total Annual Costs	-	170	257	278

<u>Effluent Quality</u>

Resulting Mass Loading

BOD5, kg/day	170	33	57	9
COD, kg/day	644	227	152	57
TSS, kg/day	38	9	10	9
Phenols, g/day	161	161	19	19
Chromium, g/day	95	95	48	47

Resulting Concentration

BOD5, mg/l	180	35	60	10
COD, mg/l	680	240	160	60
TSS, mg/l	40	10	10	10
Phenols, ug/l	170	170	20	20
Chromium, ug/l	100	100	50	50

TABLE VIII-50
MODEL PLANT CONTROL COST SUMMARY - PSNS

SUBCATEGORY: Nonwoven Manufacturing   CONTROL LEVEL: PSNS   MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

ANNUAL CAPACITY: 17,000 kkg   DAILY CAPACITY: 57 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	20	20	20
Construction	-	80	80	78
Activated Sludge				
Equipment	-	-	-	-
Construction	-	-	-	-
Chemical Coagulation				
Equipment	-	23	-	23
Construction	-	92	-	92
Vacuum Filtration				
Equipment	-	19	19	19
Construction	-	34	34	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	24	24	24
Construction	-	98	98	98
Activated Carbon				
Equipment	-	-	320	320
Construction	-	-	320	320
Monitoring	-	15	15	15
Engineering	-	40	80	90
Contingencies	-	61	139	157
Total Investment Costs	-	503	1147	1289

SUBCATEGORY: Nonwoven Manufacturing CONTROL LEVEL: PSNS MODEL FLOW: 2,271 (0.6) cu m/day (mgd)

Annual Costs				
Capital	-	50	115	129
Depreciation	-	27	56	63
Useful Life (years)	-	17	19	19
O&M Labor	-	85	93	99
Employees (persons)	-	3.8	4.1	4.4
Maintenance	-	26	23	31
Sludge Disposal	-	5	4	5
Energy & Power	-	3	10	11
Chemicals: Polymer	-	-	-	-
Alum	-	8	-	8
Carbon	-	-	26	26
Monitoring	-	13	13	13
Total Annual Costs	-	217	340	351
Effluent Quality				
				Resulting Mass Loading
BOD_5, kg/day	409	68	125	23
COD, kg/day	5367	568	1317	136
TSS, kg/day	182	23	23	23
Phenols, g/day	91	91	11	11
Chromium, g/day	23	23	11	11
				Resulting Concentration
BOD_5, mg/l	180	30	55	10
COD, mg/l	2360	250	580	60
TSS, mg/l	80	10	10	10
Phenols, ug/l	40	40	5	5
Chromium, ug/l	10	10	5	5

TABLE VIII-51
MODEL PLANT CONTROL COST SUMMARY - PSNS

SUBCATEGORY: Felted Fabric Processing   CONTROL LEVEL: PSNS   MODEL FLOW: 946 (0.25) cu m/day (mgd)

ANNUAL CAPACITY: 1,300 kkg   DAILY CAPACITY: 4.4 kkg

	Treatment Alternative			
	A	R	S	T
	Cost, thousands of dollars			
Investment Costs				
Preliminary Treatment				
Equipment	-	16	16	16
Construction	-	65	65	65
Activated Sludge				
Equipment	-	-	-	-
Construction	-	-	-	-
Chemical Coagulation				
Equipment	-	13	-	13
Construction	-	52	-	52
Vacuum Filtration				
Equipment	-	19	19	19
Construction	-	34	34	34
Dissolved Air Flotation				
Equipment	-	-	-	-
Construction	-	-	-	-
Multi-Media Filtration				
Equipment	-	14	14	14
Construction	-	56	56	56
Activated Carbon				
Equipment	-	-	280	280
Construction	-	-	280	280
Monitoring	-	15	15	15
Engineering	-	31	67	73
Contingencies	-	43	117	127
Total Investment Costs	-	358	963	1043

SUBCATEGORY: Felted Fabric Processing CONTROL LEVEL: PSNS MODEL FLOW: 946 (0.25) cu m/day (mgd)

Annual Costs				
Capital	-	36	96	104
Depreciation	-	19	47	51
Useful Life (years)	-	17	19	19
O&M Labor	-	69	72	76
Employees (persons)	-	3.1	3.2	3.4
Maintenance	-	13	12	15
Sludge Disposal	-	4	2	4
Energy & Power	-	2	4	5
Chemicals: Polymer	-	-	-	-
Alum	-	3	-	3
Carbon	-	-	10	10
Monitoring	-	3	13	13
Total Annual Costs	-	158	257	280
Effluent Quality				
				Resulting Mass Loading
BOD5, kg/day	190	33	57	9
COD, kg/day	521	199	114	47
TSS, kg/day	114	9	10	9
Phenols, g/day	550	550	57	57
Chromium, g/day	-	-	-	-
				Resulting Concentration
BOD5, mg/l	200	35	60	10
COD, mg/l	550	210	120	50
TSS, mg/l	120	10	10	10
Phenols, ug/l	580	580	60	60
Chromium, ug/l	-	-	-	-

consumption values per unit of production for the selected subcategories are as follows:

Subcategory	No. of Mills	Median Mill gt/kkg*	Consumption Btu/lb
1. Wool Scouring	8	18.7	8,100
2. Wool Finishing	15	16.0	26,000
5. Knit Fabric Finishing**	75	40.9	18,000
6. Carpet Finishing	25	21.2	9,100
8. Nonwoven Manufacturing	10	19.6	8,400

* gigJoules (billions of Joules) per kkg of production
** excluding Hosiery Products manufacturing.

The maximum energy requirement for each end-of-pipe treatment alternative for each of the selected subcategories was expressed as a percentage of the base value to determine the additional energy requirements per unit of production. The results are presented in Table VIII-52. The estimated additional energy requirements for Alternatives B, C, D, E, and F (Table VIII-1) are all well under 2 percent. For Alternatves G, H, J, and K, which involve ozonation, the additional energy requirements range from 2.5 to 5.5 percent. For the New Source Alternatives R, S, and T (Table VIII-27), the requirements range from approximately 1 to 2 percent of the total mill energy consumption.

SLUDGE MANAGEMENT

Current Practices

Useful questionnaire information on wastewater sludge management practices was received from 78 mills; 15 indirect and 63 direct dischargers. In addition, some mills indicated that their systems do not generate any significant quantities of excess sludge. It is likely that the very long detention periods employed in some biological treatment systems in the industry result in very low sludge production levels. Also, excess sludge may settle and gradually accumulate in some treatment basins.

Sixty-seven of the 78 mills had biological sludges to be processed and disposed of. Of the 11 remaining mills, one provides simple screening and flotation of its wastewaters prior to discharge to a POTW. The screenings and float are disposed of in a landfill without processing. The remaining 10 mills produce a sludge through coagulation or chemical pH adjustment. The effluent from 8 of these mills is discharged to POTW. In all cases, the sludge is removed to a landfill

TABLE VIII-52
ESTIMATED MAXIMUM ADDITIONAL ENERGY REQUIREMENTS BASED ON MEDIAN TOTAL MILL USAGE

Subcategory	End-of-Pipe Treatment Alternatives											
	B	C	D	E	F	G	H	J	K	R*	S*	T*
	(Percent)											
Wool Finishing	0.3	-	0.3	-	1.6	5.2	5.5	-	5.5	1.4	1.6	1.7
Knit Fabric Finishing**	0.3	0.03	0.3	0.9	1.1	3.3	3.7	3.4	3.7	1.2	1.0	1.3
Carpet Finishing	0.2	0.02	0.2	0.6	0.8	2.5	2.7	2.5	2.7	1.4	1.8	2.0
Nonwoven Manufacturing	0.5	0.03	0.5	0.6	0.9	2.6	3.0	2.7	3.0	0.8	1.1	1.6

* Based on direct discharge models requiring biological treatment.
** Excluding Hosiery Products manufacturing.

Source: Sverdrup & Parcel engineering analysis.

for disposal. Six of these mills dispose of the sludge in a wet condition; two dewater mechanically, one with a centrifuge and the other with a filter press; and three dry the sludge on sand beds prior to disposal.

In evaluating the management practices of the 67 reported mill treatment facilities that produce biological sludges, consideration was given to both the processing and the disposal of the sludges. Processing usually encompasses two aspects, stabilization and dewatering. Stabilization, or digestion, of the putrescible organic materials in biological sludges reduces the potential for odors and other nuisance conditions and reduces pathogenic bacteria populations. Dewatering removes excess free water to improve handling characteristics and reduce transportation costs. Disposal refers to the final disposition of the sludge.

Stabilizaton may be accomplished internally within the activated sludge or other biological process by retaining the solids for extended periods or externally in separate sludge digesters. Eighteen mills have sludge digesters, all aerobic except one anaerobic unit. The rest provide some degree of internal stabilization within the aeration basins. For this study, internal aeration periods of greater than 48 hours were regarded as providing full stabilization; shorter periods, as partial or no stabilization.

Dewatering usually refers to mechanical processes that force the excess water out of the sludge producing a mass that does not flow or drip and contains roughly 80 percent or less water by weight. Eight mills provide mechanical dewatering systems; four vacuum filters, three centrifuges, and one filter press.

A more complete form of water removal is provided by the use of sand drying beds. Twenty-four mills use sand drying beds prior to disposal.

The questionnaire responses about sludge disposal practices were classified as landfill, land application, or on-site lagoons. The term "landfill" refers to land disposal sites ranging from sanitary landfills to dumps. Three of the mills reported the use of on-site landfills. Land application refers to spraying wet sludge or spreading dry sludge solids over land surfaces to reuse some of the organic components of the sludge.

The reported sludge processing and disposal practices are summarized in Table VIII-53. Most of the mills provide full stabilization of biological sludges and some form of excess water removal. Over 70 percent of the mills dispose of their sludge in landfills with the remaining split about evenly between land application and long-term on-site storage in lagoons.

TABLE VIII-53
CURRENT SLUDGE MANAGEMENT PRACTICES

	Numbers of Mill Treatment Facilities			
Sludges Type	Landfill	Land Application	Lagoons	POTWs
Wet Biological				
Partial Stabilization	7	1	3	1
Full Stabilization	10	6	6	1
Dewatered Biological				
Partial Stabilization	-	-	-	-
Full Stabilization	8	-	-	-
Dry Biological				
Partial Stabilization	2	-	-	-
Full Stabilization	19	3	-	-
Wet Chemical	5	-	-	-
Dewatered Chemical	2	-	-	-
Dry Chemical	3	-	-	-

Source: Sverdrup & Parcel Textile Industry Survey, 1976-77.

Sludge Quantities

The questionnaire information on quantities of excess sludge to be disposed of and the associated costs of processing and removal varied widely among the mills that provided data. In most cases, the water content of the sludge was not reported, and the questionnaire data, expressed in terms of either volume or weight, could not be correlated with other information about the type of treatment provided or the mill production level.

Fourteen mills reported biological sludge volumes ranging from 0.8 to 182 liters/cu m (0.2 to 48 gal/1000 gal) of wastewater treated. The median value for these mills was approximately 23 liters/cu m (6 gal/1000 gal). The wide range of values reflect differences in aeration detention periods, loading rates, ambient temperatures, etc. For reference, typical sludge production rates for conventional (8-hour) activated sludge plants treating domestic sewage is 76 liters/cu m (20 gal/1000 gal).

The estimated quantities of excess sludge generated by the various end-of-pipe treatment alternatives for the model plants are presented in Table VIII-54 for direct dischargers and Table VIII-55 for indirect dischargers. The values are expressed in metric tons per year of dewatered sludge containing 20 percent solids.

OTHER NON-WATER QUALITY ASPECTS

At this time, there are be no known significant other non-water quality environmental impacts in terms of air pollution, noise, or radiation from application of any of the alternative end-of-pipe treatment alternatives.

A non-water quality aspect relating to air quality that is not peculiar to the textile industry is the possible stripping of volatile toxic and other pollutants in treatment systems, particularly in activated sludge aeration basins. A preliminary review of the data from the field sampling program indicates that some of the Group 1 toxic pollutants that are generally regarded as being very resistant to biodegradation are often removed substantially during passage of the wastewater through secondary treatment systems. Release to the atmosphere is theoretically possible, but has not been measured at this time. The possible impact on air quality has not been evaluated.

TABLE VIII-54
ESTIMATED QUANTITIES OF DEWATERED SLUDGE FOR REPRESENTATIVE MODEL PLANTS*
DIRECT DISCHARGERS

Subcategory	End-of-Pipe Treatment Alternatives												
	A	B	C	D	E	F	G	H**	J**	K**	R	S	T
	(Metric Tons/Year)												
1. Wool Scouring													
Existing Sources	180	-	-	-	-	-	-	670	930	670	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Wool Finishing													
Existing Sources	2200	890	-	1100	-	1100	0	890	-	1100	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	3200	1300	1700
4. Woven Fabric Finishing													
a. Simple Processing													
Existing Sources	890	260	70	330	70	330	0	260	70	330	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	1200	550	710
b. Complex Processing													
Existing Sources	4000	1300	680	1600	680	1600	0	1300	680	1600	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	5300	2700	3600
c. Complex Processing													
Existing Sources	2200	640	340	810	170	810	0	640	340	810	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	2800	1300	2000
5. Knit Fabric Finishing													
a. Simple Processing													
Existing Sources	1400	430	110	540	110	540	0	430	110	540	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	1900	950	1100

Source: Sverdrup & Parcel engineering analysis.

TABLE VIII-54 (Continued)

Subcategory	A	B	C	D	E	F	G	H**	J**	K**	R	S	T
	End-of-Pipe Treatment Alternatives												
	(Metric Tons/Year)												
b. Complex Processing													
Existing Sources	890	260	140	330	140	330	0	260	140	330	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	1300	410	710
c. Hosiery Products													
Existing Sources	180	60	-	80	-	320	0	60	-	80	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	280	-	530
6. Carpet Finishing													
Existing Sources	380	110	60	140	60	140	0	110	60	140	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	540	440	540
7. Stock & Yarn Finishing													
Existing Sources	890	260	70	330	70	330	0	260	70	330	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	1200	410	710
8. Nonwoven Manufacturing													
Existing Sources	180	60	20	70	270	310	0	60	30	70	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	540	440	540
9. Felted Fabric Processing													
Existing Sources	180	60	-	80	-	320	0	60	-	80	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	560	440	560

* Quantities based on 20 percent solids content.

** Alternatives H, J and K represent alternatives M, N and P, respectively, for Subcategory 1 only.

Source: Sverdrup & Parcel engineering analysis.

TABLE VIII-55
ESTIMATED QUANTITIES OF DEWATERED SLUDGE FOR REPRESENTATIVE MODEL PLANTS*
INDIRECT DISCHARGERS

Subcategory	End-of-Pipe Treatment Alternatives												
	A	B	C	D	E	F	G	H**	J**	K**	R	S	T
	(Metric Tons/Year)												
1. Wool Scouring													
Existing Sources	-	-	-	-	-	-	-	3950	4000	3950	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Wool Finishing													
Existing Sources	-	640	-	810	-	810	-	640	340	-	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	1100	750	1100
4. Woven Fabric Finishing													
a. Simple Processing													
Existing Sources	-	150	-	170	-	170	-	150	60	-	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	110	130	110
b. Complex Processing													
Existing Sources	-	490	-	500	-	500	-	490	-	-	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	500	310	500
c. Complex Processing													
Existing Sources	-	1200	-	1260	-	1260	-	1200	-	-	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	1400	750	1500
5. Knit Fabric Finishing													
a. Simple Processing													
Existing Sources	-	260	-	330	-	330	-	260	140	-	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	250	310	250

Source: Sverdrup & Parcel engineering analysis.

TABLE VIII-55 (Continued)

Subcategory	A	B	C	D	E	F	G	H**	J**	K**	R	S	T
	End-of-Pipe Treatment Alternatives (Metric Tons/Year)												
b. Complex Processing													
Existing Sources	-	360	-	490	-	490	-	360	140	-	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	470	310	470
c. Hosiery Products													
Existing Sources	-	150	-	170	-	170	-	150	60	-	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	200	130	200
6. Carpet Finishing													
Existing Sources	-	360	-	420	-	420	-	360	140	-	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	470	310	470
7. Stock & Yarn Finishing													
Existing Sources	-	110	-	140	-	140	-	110	60	-	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	110	130	110
8. Nonwoven Manufacturing													
Existing Sources	-	360	-	490	-	490	-	360	140	-	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	470	310	470
9. Felted Fabric Processing													
Existing Sources	-	200	-	230	-	230	-	200	-	-	-	-	-
New Sources	-	-	-	-	-	-	-	-	-	-	240	130	240

* Quantities based on 20 percent solids content.
** Alternatives H, J and K represent alternatives M, N and P, respectively, for Subcategory 1 only.

Source: Sverdrup & Parcel engineering analysis.

SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE EFFLUENT LIMITATIONS GUIDELINES

INTRODUCTION

The effluent limitations that must be achieved by July 1, 1984, are determined by identifying the very best control and treatment technology employed by a specific point source within the industrial category or subcategory or by one industry where it is readily transferable to another. A specific finding must be made as to the availability of control measures and practices to eliminate the discharge of pollutants, taking into account the cost of such elimination.

Consideration was also given to:

- The age of the equipment and facilities;
- The processes employed;
- The engineering aspects of the application of various types of control techniques;
- Process changes; and
- Non-water quality environmental impact (including energy requirements).

The Best Available Technology Economically Achievable (BAT) emphasizes in-process controls as well as control or additional treatment techniques employed at the end of the production process. It considers those plant processes and control technologies which, at the pilot plant semi-works, and other levels, have demonstrated both technological performances and economic viability at a level sufficient to reasonably justify investing in such facilities. It is the highest degree of control technology that has been achieved or has been demonstrated to be capable of being designed for plant-scale operation up to and including "no discharge" of pollutants. Although economic factors are considered in this development, the costs of this level of control are intended to be the top-of-the-line of current technology, subject to limitations imposed by economic and engineering feasibility. There may be some technical risk, however, with respect to performance and certainty of costs. Therefore, some process development and adaptation may be necessary for application at a specific mill site.

IDENTIFICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY ACHIEVABLE

Best Practicable Control Technology Currently Available (BPT) is the basis for the present level of control for direct dischargers in the textile industry. As defined in the earlier Development Document (1), BPT includes preliminary screening, primary settling (Wool Scouring Subcategory only), latex coagulation (Carpet Mills Subcategory only), and secondary biological treatment. Effluent limitations guidelines representing the degree of effluent reduction attainable by the application of BPT are detailed in the Federal Register (40 CFR 410; 39 FR 24736, July 5, 1974; Amended by 39 FR 30134, August 20, 1974; 42 FR 26979, May 26, 1977).

IDENTIFICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

BAT utilizes BPT as a basis for further improvements. No special in-plant modification is required. In-plant control measures and additional end-of-pipe treatment technology available to improve BPT are listed below. The control measures listed are fully discussed in Section VII, and the operating characteristics of the end-of-pipe technologies are presented in Section VIII.

In-Plant Control Measures

- Water reuse
- Water reduction through conservation
- Chemical substitution
- Material reclamation for reuse
- Process changes
- Segregation of concentrated waste streams for separate treatment
- Production scheduling to distribute loading

End-of-Pipe Treatment Technology

LEVEL 1 - CURRENT LEVEL OF TREATMENT (BPT) - Biological treatment (extended-aeration activated sludge)
LEVEL 2 - Biological treatment plus filtration
LEVEL 3 - Biological treatment plus chemical coagulation
LEVEL 4 - Biological treatment plus chemical coagulation and filtration

More sophisticated end-of-pipe treatment levels involving activated carbon or ozone added to above levels were evaluated technically but were not considered in establishing the BAT level of control because they are too costly relative to the resulting benefits.

Based on analyses of these control options, the Agency has selected LEVEL 2 for Woven Fabric Finishing (all subdivisions), Knit Fabric Finishing (except the Hosiery Products Subdivision), Carpet Finishing, Stock & Yarn Finishing, and Nonwoven Manufacturing, LEVEL 4 for Wool Scouring, Wool Finishing, and the Hosiery Products Subdivision of Knit Fabric Finishing, and LEVEL 1 for Felted Fabric Processing as the basis for BAT effluent limitations. For Wool Scouring, the technology includes dissolved air flotation in place of filtration because of the nature of the solids.

The current level of treatment, BPT, properly operated and with appropriate in-plant control measures or preliminary treatment, will permit some mills in the industry to comply with the BAT effluent limitations without instituting additional end-of-pipe treatment. Some mills, on the other hand, may find it necessary or more cost effective to go to a higher treatment level in order to comply with BAT effluent limitations.

BAT EFFLUENT LIMITATIONS

Subcategory 1 - Wool Scouring

Effluent Limitations, kg/kkg of raw grease wool

Pollutant or Pollutant Property	Maximum for any one day	Average of daily values for 30 consecutive days
COD	36.3	24.6
TSS	10.9	6.3
Total Phenol	0.002	0.001
Total Chromium	0.01	0.006
Total Copper	0.01	0.006
Total Zinc	0.02	0.01
Color (ADMI units)	2400	1500

Subcategory 2 - Wool Finishing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
COD	82.4	56.2
TSS	11.0	6.4
Total Phenol	0.032	0.018
Total Chromium	0.26	0.14
Total Copper	0.26	0.14
Total Zinc	0.52	0.28
Color (ADMI units)	190	120

Subcategory 3 - Low Water Use Processing

This subcategory is excluded from BAT effluent limitations.

Subcategory 4a - Woven Fabric Finishing, Simple Processing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
COD	33.1	22.6
TSS	3.4	2.0
Total Phenol	0.005	0.003
Total Chromium	0.07	0.04
Total Copper	0.07	0.04
Total Zinc	0.14	0.08
Color (ADMI units)	340	220

Subcategory 4b - Woven Fabric Finishing, Complex Processing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Average of daily values for 30 consecutive days
COD	38.1	26.0
TSS	4.7	2.7
Total Phenol	0.013	0.008
Total Chromium	0.08	0.04
Total Copper	0.08	0.04
Total Zinc	0.16	0.08
Color (ADMI units)	340	220

Subcategory 4c - Woven Fabric Finishing, Complex Processing Plus Desizing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Average of daily values for 30 consecutive days
COD	49.9	34.0
TSS	6.2	3.6
Total Phenol	0.012	0.007
Total Chromium	0.10	0.06
Total Copper	0.10	0.06
Total Zinc	0.20	0.11
Color (ADMI units)	340	220

Subcategory 5a - Knit Fabric Finishing, Simple Processing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Average of daily values for 30 consecutive days
COD	64.6	44.0
TSS	5.2	3.0
Total Phenol	0.018	0.010
Total Chromium	0.12	0.07
Total Copper	0.12	0.07
Total Zinc	0.24	0.14
Color (ADMI units)	340	220

Subcategory 5b - Knit Fabric Finishing, Complex Processing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Average of daily values for 30 consecutive days
COD	41.1	28.0
TSS	5.0	2.9
Total Phenol	0.011	0.006
Total Chromium	0.08	0.04
Total Copper	0.08	0.04
Total Zinc	0.15	0.08
Color (ADMI units)	340	220

Subcategory 5c - Knit Fabric Finishing, Hosiery Products

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
COD	47.7	32.5
TSS	7.0	4.0
Total Phenol	0.006	0.003
Total Chromium	0.06	0.03
Total Copper	0.06	0.03
Total Zinc	0.12	0.07
Color (ADMI units)	190	120

Subcategory 6 - Carpet Finishing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
COD	23.8	16.3
TSS	3.0	1.8
Total Phenol	0.010	0.006
Total Chromium	0.04	0.02
Total Copper	0.04	0.02
Total Zinc	0.08	0.05
Color (ADMI units)	340	220

Subcategory 7 - Stock & Yarn Finishing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	Average of daily values for 30 consecutive days
COD	24.7	16.8
TSS	2.7	1.6
Total Phenol	0.013	0.008
Total Chromium	0.09	0.05
Total Copper	0.09	0.05
Total Zinc	0.18	0.10
Color (ADMI units)	340	220

Subcategory 8 - Nonwoven Manufacturing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	Average of daily values for 30 consecutive days
COD	39.8	27.1
TSS	3.3	1.9
Total Phenol	0.002	0.001
Total Chromium	0.04	0.02
Total Copper	0.04	0.02
Total Zinc	0.07	0.04
Color (ADMI units)	340	220

Subcategory 9 - Felted Fabric Processing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Average of daily values for 30 consecutive days
COD	143.0	97.0
TSS	62.0	36.0
Total Phenol	0.05	0.03
Total Chromium	0.19	0.11
Total Copper	0.19	0.11
Total Zinc	0.38	0.21
Color (ADMI units)	380	240

METHODOLOGY USED TO DEVELOP BAT EFFLUENT LIMITATIONS

The rationale and method used in developing the BAT effluent limitations are described below.

Rationale

The current wastewater management practices of the textile industry were investigated and the performances of existing BPT systems were evaluated in detail. It was found that many such systems are capable of controlling conventional, non-conventional, and toxic pollutants when properly designed, operated, and maintained and when in-plant controls are provided as necessary to prevent overload or other abuse of the end-of-pipe treatment facilities. The available data indicate that many BPT systems are currently discharging effluent levels that could not be significantly improved without resorting to sophisticated and very costly treatment technologies. The data also show that some other BPT systems in the textile industry either almost achieve such effluent quality or achieve it intermittently. In light of these findings, the Agency has concluded that BPT, when functioning optimally or when upgraded by the application of filtration or chemical coagulation, or both, constitutes BAT. In other words, many textile mills are capable of meeting the BAT effluent limitations without additional end-of-pipe technology. Through the use of in-plant measures, as described in Section VII, and through improvements in the operation and/or design of the BPT systems, such mills can consistently provide control of all conventional, non-conventional, and toxic pollutants.

It is also recognized that a number of textile mills may find it necessary or cost-effective to implement additional treatment to meet the BAT effluent limitations. Because of variations among mills within the same subcategory of the textile industry, not all can benefit equally from the application of the same in-plant control measures and end-of-pipe treatment technologies. In order to permit flexibility in meeting the BAT effluent limitations, more than one alternative is considered to be appropriate, depending upon the requirements of individual mills. The alternative unit treatment processes, filtration and chemical coagulation, provide different methods of removing the same principal target pollutant; namely, TSS. Both processes have been used in the industry to upgrade BPT systems, and both have been demonstrated at full-scale or in pilot-plant studies, or both, in all subcategories of the industry except Nonwoven Manufacturing (Subcategory 8) and Felted Fabric Processing (Subcategory 9).

Method

The Agency developed the effluent limitations in a building block fashion by engineering analysis using full-scale and pilot-scale treatability data. First, median BPT effluent concentration levels were established for the conventional and non-conventional pollutants for each subcategory and internal subdivisions of subcategories (Table V-9). Long-term data were available from NPDES permit monitoring reports and the industry survey questionnaires. Second, separate statistical analyses were carried out for BOD_5, COD, TSS, color, and total phenol at selected, well-operated textile waste treatment facilities to determine the normal and seasonal variability of the data. A summary of these analyses is provided in Table IX-1, which presents the median average month, maximum month, and maximum day long-term monitoring values for the mills reporting such data and the medians of the calculated maximum month/average month and maximum day/average day ratios for these mills. The median BPT effluent concentration values were adjusted by the median maximum month/ average month value for each pollutant. The concentrations were converted to mass loadings (kg/kkg of finished product) by applying the median water usage values for each subcategory (Table V-1) to provide the basis for the 30-day average limitations. The basis for the maximum daily limitations was application of specific factors to the 30-day average limitations that were determined by dividing the median maximum day/average month values by the median maximum month/average month values in Table IX-1. Finally, effluent limitations based on the BAT option selected were calculated for both the 30-day average and maximum day by application of median treatment performance values established from the results of the EPA/Industry

TABLE IX-1

SUMMARY OF BPT VARIABILITY - CONVENTIONAL AND NON-CONVENTIONAL POLLUTANTS

Pollutant Parameter	No. of Plants*	Median of Reported Values** Average Month# mg/l	Maximum Month mg/l	Maximum Day mg/l	Median of Calculated Values## Maximum Month/ Average Month	Maximum Day/ Average Month
BOD5	36/36/34	17.7	28.6	55.0	1.8	3.1 (3.1)+
COD	33/33/32	233	392	613	1.5	2.2 (2.2)+
TSS	36/36/34	42.5	74.0	141	1.8	3.2 (3.1)+
Color (ADMI units)	6/6/4	171	264	400	1.6	2.5 (2.5)+
Total Phenol	14/14/13	0.063	0.099	0.145	1.8	2.6 (3.1)+

* Values represent number of plants reporting average month, maximum month, and maximum day data, respectively.

** Values represent the median of the average month, maximum month, and maximum day values reported for the mills with long-term monitoring data.

\# Mean of monthly mean concentrations.

\## Values represent the median of the values calculated for the mills with long-term monitoring data.

\+ Values used in calculating effluent limitations.

Pilot Plant Research Project. Statistical summaries of the performance data are presented in Table IX-2 for multi-media filtration and Table IX-3 for chemical coagulation and multi-media filtration.

REGULATED POLLUTANTS

Non-conventional Pollutants

The non-conventional pollutants limited by BAT are color, as measured by the ADMI procedure, and COD. These pollutants can produce detrimental effects in receiving waters and are limited to prevent such effects. Color limitations are expressed in standard ADMI units.

High color levels in textile mill discharges result primarily from dyes and printing pastes, except in Subcategory 1, Wool Scouring. Dyes comprise a wide variety of chemical structures and their behavior is dependent upon environmental conditions. Because of their variety, there is no single treatment process that will control color in all textile mill wastewaters. Limited data from the sampling program show activated carbon adsorption to be most effective in reducing color. Filtration is generally ineffective, while chemical coagulation has been found to be effective, but not in all applications. Mills with severe color problems will have to develop suitable control measures.

Toxic Pollutants

The toxic pollutants expressly controlled for direct dischargers in each subcategory are "total phenol," and the following metallic priority pollutants: total chromium, total copper, and total zinc. These pollutants are subject to numerical limitations expressed in kilograms per thousand kilograms (kg/kkg) of product (lbs/1000 lbs). Since the Agency has adopted the control of TSS as an "indicator pollutant" as the basis for controlling toxic pollutants, no effluent limitations are recommended for any toxic pollutants other than those listed here.

"Total phenol" is measured by the 4-aminoantipyrine method (4AAP). This method measures the simple phenol present, plus fractions of other specific substituted phenols, such as 2,4,6-trichlorophenol. While pentachlorophenol does not respond to this test, the Agency concludes that when both total phenol and TSS are controlled, this compound and other compounds resistant to rapid biodegradation will be controlled as well.

Total chromium, total copper, and total zinc are regulated because they were detected at relatively high concentrations in the raw wastes at some textile mills. Other metallic toxic pollutants detected at lower concentrations and generally less frequently included antimony,

TABLE IX-2
STATISTICAL SUMMARY - TREATMENT PERFORMANCE DATA
MULTI-MEDIA FILTRATION

Pollutant Parameter	No. of Plants*	Minimum	Maximum	Average	Median	
BOD5						
Effluent, mg/l	14	3	23	10	8.5	
Removal, %	14	7	79	34	27	(25)#
COD						
Effluent, mg/l	14	55	630	210	109	
Removal, %	14	0	40	20	23	(20)#
TSS						
Effluent, mg/l	14	4	85	18	11	
Removal, %	14	19	92	59	67	(65)#
Color						
Effluent, ADMI units	12	97	384	208	188	
Removal, %	12	0	44	10	5	(10)#
Total Phenol						
Effluent, mg/l	3	0.04	0.08	0.058	0.053	
Removal, %	3	7	33	24	33	(30)#

* Number of mills for which treatment performance data were obtained for the pollutant parameter.

\# Removal values used in calculating effluent limitations.

TABLE IX-3
STATISTICAL SUMMARY - TREATMENT PERFORMANCE DATA
CHEMICAL COAGULATION PLUS MULTI-MEDIA FILTRATION

Pollutant Parameter	No. of Plants*	Minimum	Maximum	Average	Median	
BOD5						
Effluent, mg/l	10	2	31	10	6.5	
Removal, %	10	45	85	66	66	(65)#
COD						
Effluent, mg/l	10	67	807	208	134	
Removal, %	10	16	85	46	48	(45)#
TSS						
Effluent, mg/l	10	2	102	23	11	
Removal, %	10	24	99	70	72	(75)#
Color						
Effluent, ADMI units	9	55	626	199	168	
Removal, %	9	0	73	43	58	(50)#
Total Phenol						
Effluent, mg/l	3	0.03	0.054	0.041	0.04	
Removal, %	3	50	69	58	55	(55)#

* Number of mills for which treatment performance data were obtained for the pollutant parameter.

\# Removal values used in calculating effluent limitations.

arsenic, cadmium, lead, mercury, nickel, selenium, and silver. Treatment processes that are effective for chromium, copper, and zinc may not be completely effective for the other metals in all cases, especially when present at high concentrations. Due to the varied nature of the textile industry and the necessarily limited extent of the screening and verification sampling programs, these unregulated metallic pollutants may be a problem at some textile mills, and limitations at the local level may be required.

Indicator Pollutant

The difficulties of toxic pollutant analyses for other toxics has prompted EPA to propose a new method of regulating certain toxic pollutants. For certain toxic pollutants, for which historical data are limited and inexpensive analytical methods are not well developed, EPA is proposing numerical limitations for the "indicator pollutant," TSS. The data available to the Agency revealed that when this "indicator pollutant" is controlled, the concentrations of toxic pollutants are significantly lower than when the "indicator pollutant" is present in high concentrations.

EPA's consideration of "indicator" limitations was brought to the attention of Congress during the formative stages of the Clean Water Act of 1977. At that time, EPA was examining several techniques to alleviate the difficulties of lengthy and expensive analytical procedures. The proposed alternate "indicator" limitations serve that purpose. This method of toxics regulation obviates the difficulties, high costs, and delays of monitoring and analyses that would result from limitations solely on the toxic pollutants.

Table C-2 in the Appendix is a list of toxic pollutants that were detected in treated effluents in concentrations greater than available analytical detection limits. The Agency concludes that these pollutants will be effectively controlled by limitation of the "indicator pollutant" even though the toxics (other than total phenol and the above listed metals) are not expressly regulated by numerical limitations.

The toxic pollutants regulated by the "indicator pollutant" include all of the volatile (purgeable) organics, some of the acid extractable organic compounds, the base-neutral extractable organic compounds, and the inorganic compounds.

Effective control of suspended solids has been shown to provide reductions of toxic inorganic pollutants and certain toxic organic compounds. Control of TSS is, therefore, an indicator for certain toxic pollutants, in addition to being a conventional pollutant of major concern.

It should be noted that the "indicator pollutant" TSS is classified as a "conventional" pollutant under Section 304(a)(4) of the Act or proposed regulations. Where conventional pollutants are used as "indicator pollutants" for toxic pollutants, BAT limitations for these pollutants have been established to assure installation and performance of waste treatment technology that is adequate for the removal of toxic pollutants.

<u>SIZE, AGE, PROCESSES EMPLOYED, LOCATION OF FACILITIES</u>

The textile industry includes operations ranging in size from small shops to large complexes with thousands of employees. The manufacturing processes employed are determined by the fiber types (raw materials), final products, and the type of finishing operations used. These process-related factors have been considered and incorporated into the subcategorization. The processes employed in different sized textile mills within each subcategory are essentially the same. The industry has generally modernized its equipment and facilities as new methods that are economically attractive have been introduced. No relationship between size and age and the constitutive characteristics of the wastewaters within each subcategory was found to exist, as described in detail in Section IV. Facilities located in cold climates can employ the same control technologies as those in warmer climates by incorporating well established design principles and operating procedures to compensate for the effects of winter conditions on biological and physico-chemical treatment systems.

In summary, the factor of processes employed is included in the subcategorization. The factors of size, age, and location of facilities do not affect the technology that can be applied effectively in each subcategory.

<u>ENGINEERING ASPECTS OF BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE</u>

The characteristics of the wastewaters from the various subcategories of the textile industry are described in Section V. Because there is diversity in raw materials, processing methods, process control, and final products, there are variations in raw wastewater characteristics among mills within each subcategory. Despite these variations, textile mill wastewaters are generally susceptible to treatment by biological systems designed to accommodate the characteristics of the particular mill where applied.

The overall approach in developing BAT was to use biological treatment (BPT) as the base. Its performance would be optimized through in-plant control measures, additional preliminary treatment as appropriate, and improved control and operation of the existing biological system components. Additional end-of-pipe treatment technologies would be employed only as required. Since filtration and chemical coagulation overlap in terms of target pollutants, it is expected that relatively few mills will need to install both processes to meet the BAT effluent limitations.

In-Plant Control Measures and Process Changes

In-plant control measures are described in detail in Section VII. In-plant process changes that reduced the wastewater quantity or pollutant loading have been implemented at many mills for purely economic reasons, with the side benefit of improved wastewater quality. Polyvinyl Alcohol (PVA) recovery and reuse is an example of such decision-making within the industry. Other examples are countercurrent flows in rinsing operations, substitution of alternatives for chromium-based dyes, and pressurized dyeing baths, all of which have been used successfully within the industry. Other measures, such as segregation of concentrated waste streams to permit separate preliminary treatment or reuse and scheduling of production to distribute waste loadings, may find appropriate applications in the industry. Many textile mills can also benefit significantly from improved housekeeping, better control of spills and dumps, installation of preliminary flow equalization, and closer control of treatment facility operation by providing additional trained personnel.

Many textile mills have implemented one or more of the above measures beneficially, providing demonstrative evidence of their applicability. However, not all mills can implement all such measures because of differences in production methods and site-specific characteristics. Also, there are no such in-plant measures that are obviously lacking in most mills in the industry or in any subcategory. There is evidence, however, that there are many mills that could benefit more from implementing such measures than from installing end-of-pipe technologies that are larger or more sophisticated than necessary. One area that has not yet received much attention is elimination or reduction of toxic pollutants in the mill wastewaters through raw material substitution.

Existing End-of-Pipe Treatment Facilities

Over the years, the industry has carried out much research on the application of biological treatment to textile finishing wastewaters. The system in most common use today is a sequence comprising screens, aeration basin, and secondary clarification. Equalization for approximately 24 hours and/or neutralization prior to aeration is included in many systems. The systems are basically aerated lagoons with suspended solids recycle to provide the extended-aeration mode of the activated sludge process. A relatively wide range of design criteria have been used, as documented in Section VII. Theoretical aeration basin detention periods range from 1 to 6 or more days, with about 3 days being typical. It is likely that actual detention periods are shorter in many installations because of accumulations of bottom solids that decrease the effective depth of the basin. Mixed liquor suspended solids typically range from 1,500 to 6,000 mg/l and, with the long detention periods (large aeration basin volume), the theoretical F:M ratios and excess sludge production rates are very low. As noted in Section VIII, some mills reported that their treatment facilities required no regular sludge removal and wasting program because "no excess sludge is produced."

While these biological treatment systems are relatively rugged and do not require constant attention, they are subject to neglect and abuse through overloading. Field observations confirmed that many facilities are not properly designed, operated, or maintained, and it is evident that better treatment results would accrue from improvement of these aspects. Upgrading of existing systems and the provision of closer operating controls and scheduled maintenance programs will be both beneficial and necessary in order that additional treatment components function effectively and economically. Simply appending new treatment components to BPT facilities that are not performing effectively may not solve the problem. It is likely that problems in the new units will dictate that upstream improvements be made. In essence, it is important that existing facilities be brought into optimal operational condition before designing and installing new components.

As noted above, it is expected that many mills will be able to meet the BAT effluent limitations without providing additional treatment technologies. The two treatment technologies that are available are filtration and chemical coagulation. There is evidence that some mills cannot use filtration because the TSS levels in the BPT effluent are too high for effective operation of the filters. There is also some limited evidence that the conventional chemical coagulants do not always work effectively because of the chemical characteristics of the wastewaters from some mills. Either filtration or chemical coagulation has been the choice to date among most of the mills in the industry that have implemented treatment levels beyond BPT. These technologies have also been demonstrated in several other industrial point source categories.

Filtration

Filtration is a unit process that has been used for many decades in the water supply field. In recent years, it has seen increased application for polishing secondary municipal treatment effluents and wastewaters from steel mills, grain processing plants, and other industries. Ten direct dischargers in the textile industry currently include some form of filtration in their waste treatment facilities.

Filtration functions to reduce suspended solids (TSS). Some fraction of the BOD_5 and the COD comprises suspended solids and these parameters are also reduced by filtration. Certain dissolved organic compounds may become associated with the suspended solids and be removed also, further reducing the BOD_5 and the COD. At this time, information is generally lacking by which to document or explain the removal of dissolved organic constituents by filtration. Such factors as removal mechanisms, optimal conditions, and the nature of interferences make reliable predictions impractical at this time.

Based on the filtration data available, generally positive correlations were found between control of the "indicator pollutant" TSS and control of the significant organic toxic pollutants. Two exceptions were the pollutants chloroform and trichloroethylene. Plain filtration was not found to be effective for reducing relatively low concentrations of metallic toxic pollutants. Data from municipal wastewater treatment facilities indicate that high removals of metals are achieved when TSS removals are very high. It seems likely that the metals in textile mill wastewaters that pass through filtration are largely in dissolved forms and, therefore, beyond the capacity of the filter. Removal of these metals would require precipitation followed by sedimentation and/or filtration.

Filtration systems that backwash automatically are common today. While filters are somewhat more sophisticated mechanically than aerated-lagoon activated sludge systems, they lend themselves to relatively routine operations schedules. The addition of filtration to existing well-operated biological treatment facilities need not require a substantial elevation of operational skills. With training, existing operators in the industry should be able to operate filters successfully.

Chemical Coagulation

Chemical coagulation has also been used for decades in the treatment of turbid water supplies for municipalities. At least six direct dischargers in the textile industry are currently employing some form of chemical coagulation. Several other facilities add coagulants ahead of or at the final clarifiers of their biological treatment systems to increase solids removal. The principal target of chemical coagulation is the group of finely divided suspended solids known as colloids. The added chemicals cause these solids to aggregate into larger particles that can be removed effectively by sedimentation or filtration, or both. The proper dosages of chemicals are determined empirically to match the fluctuations in the wastewater characteristics. The proper dosage is critical for success because too little or too much chemical will result in failure to produce coagulation. With polyelectrolytes, the critical dosage range is relatively narrow, compared to those for the more traditional coagulants such as alum, iron salts, and lime. Because of the complex of variables that influence the coagulation phenomenon and the required knowledge of chemistry, this treatment process is more sophisticated than filtration, and greater operator training and skill are required.

Much of the work on coagulation of textile mill wastewaters has focused on the use of alum as the primary coagulant. This chemical is generally less effective than lime or iron salts in removing heavy metals from wastewaters. Where metals pose a more significant problem than organic toxic pollutants, consideration should be given to coagulants other than alum. The use of lime as a coagulant may elevate the pH to levels that will make subsequent treatment, e.g., recarbonation, necessary. The use of polyelectrolytes, or polymers, in coagulation and filtration is increasing markedly. These chemicals offer the advantage of much smaller dosages and smaller resulting sludge volumes. Today, polymers can often be formulated to fit specific applications.

Based on limited coagulation data available, generally positive correlations were found for the control of metallic toxic pollutants with the control of TSS. Correlations were not as good for organics, especially chloroform and trichloroethylene. Available data for the combination of coagulation plus filtration show generally positive correlations for the control of metallic and organic toxic pollutants with the control of TSS.

NONWATER QUALITY ENVIRONMENTAL IMPACT

Currently, textile mills are classified as major sources of hazardous wastes, the principal component being sludges from wastewater treatment facilities. Data are lacking by which to determine the extent of the problem. Implementation of BAT will, in general, result in more sludge being generated, although in varying amounts at different mills. In-plant measures to eliminate or segregate toxic pollutants from the major wastewater discharge may be feasible at some mills, thereby resulting in a non-hazardous classification for most of the wastewater treatment sludge at these mills.

No significant change in atmospheric quality in terms of air emissions, noise, or radiation will result from implementation of BAT. It is suspected that some existing BPT facilities release volatile organic compounds to the atmosphere by air stripping in the aeration basin of biological systems. This phenomenon has not been measured directly and is not unique to this industrial point source category.

The estimated energy requirements in implementing BAT range from 0.02 to 0.03 percent of current mill usage for filtration and from 0.2 to

0.5 percent for chemical coagulation or chemical coagulation plus filtration.

Sludge Management

As noted above and discussed in Section VIII, the production of waste sludge in BPT treatment systems ranges widely. Some mills have no recognized sludge generation while others use mechanical stabilization and dewatering systems to process large quantities of sludge for disposal. There is no standard sludge management system in use today in the textile industry.

The addition of filtration will impact existing sludge programs differently. For mills with very low sludge production rates, the solids in the filter backwash can be returned to the system via the secondary clarifier with no appreciable change required in sludge management practices. It is likely that some mills periodically discharge undetected excessive TSS levels in their BPT effluents. The installation of filters would tend to prevent this, and such mills might find that a sludge management system would be required. For mills with existing sludge handling systems, the addition of filtration should not generally result in significantly greater quantities of sludge to be handled.

The application of chemical coagulation to BPT systems will generate significantly more sludge in almost all cases. In addition to the TSS removed, the added chemicals and certain background constituents of the water will be removed in the form of sludge. Chemical sludges differ from those from biological systems, and common processing of both may not be feasible in all cases. Chemical sludges are often difficult to dewater; alum sludge being generally more troublesome than lime sludge. The use of chemical coagulation will require a sludge management program in almost all cases.

In Section VIII, model plant costs were developed on the basis of using vacuum filtration to dewater sludges prior to disposal in sanitary landfills. Such a sludge processing system will not be feasible either technically or economically for many textile mills. A major consideration that will influence the choice of sludge system will be the flexibility of disposal allowed for sludges classified as hazardous waste under the Resource Conservation and Recovery Act (RCRA). Even without this aspect, however, there are many site-specific factors that must be considered in developing a sludge management program for a particular textile mill. The type and size of the treatment facility will be of major importance. Other factors include the availability of land and the proximity and nature of disposal sites. Some mills may be able to dispose of small quantities of sludge without dewatering. Other mills may be able to use sand drying beds or storage lagoons effectively. Others may use relatively sophisticated digestion and mechanical dewatering units prior to disposal. Presently, only a few mills dispose of their sludge on agricultural or other lands, but this practice is becoming a popular alternative. In summary, sludge management problems must be solved individually at each mill location by selecting from among the variety of alternatives that are available.

TOTAL COST OF APPLICATION

Based on the cost information in Section VIII, the total investment and associated total annualized costs for the direct dischargers in the industry to achieve the recommended BAT effluent limitations are estimated to be $48 and $21 million, respectively. EPA has determined that these costs will most likely be incurred by 214 direct dischargers. The remaining 25 mills are currently achieving BAT. This estimate is based on data which indicates that 18 mills have BAT technology in-place and 7 mills are currently achieving BAT with biological treatment.

This investment would reduce the discharge of conventional pollutants, non-conventional pollutants, and toxic pollutants that are found in the wastewaters of textile mills to the required effluent concentrations with a high degree of confidence.

GUIDANCE TO ENFORCEMENT PERSONNEL

Chromium, copper, and zinc are metallic toxic pollutants specifically regulated by BAT. Antimony, arsenic, cadmium, lead, mercury, nickel, selenium, and silver are metallic toxic pollutants that were typically identified at low concentrations in textile plant raw and treated effluents but, because of their general nature, common usage, and frequency of detection, may be a problem at some textile mills. It is recommended that EPA regional, state, and municipal enforcement personnel investigate the presence of these metals and determine their levels. The following tabulation provides the average BPT effluent concentrations of these pollutants based on the results of the field sampling program and offers guidance as to recommended allowable discharge levels. These levels should be used to determine whether additional effluent limitations are appropriate for individual direct dischargers.

Metal	Typical Concentration, ug/l
Antimony	100
Arsenic	80
Cadmium	30
Lead	60
Mercury	0.4
Nickel	80
Selenium	40
Silver	40

SECTION X

EFFLUENT REDUCTION ATTAINABLE BY BEST CONVENTIONAL POLLUTANT CONTROL TECHNOLOGY

The 1977 amendments added Section 301(b)(2)(E) to the Act, establishing "best conventional pollutant control technology" (BCT) for discharges of conventional pollutants from existing industrial point sources. Conventional pollutants are those defined in Section 304(a)(4) - BOD, TSS, fecal coliform, and pH - and any additional pollutants defined by the Administrator as "conventional."

BCT is not an additional limitation, but replaces BAT for the control of conventional pollutants. BCT requires that limitations for conventional pollutants be assessed in light of a new "cost-reasonableness" test, which involves a comparison of the cost and level of reduction of conventional pollutants from the discharge of POTW to the cost and level of reduction of such pollutants from a class or category of industrial sources. The Agency promulgated its cost test methodology on August 29, 1979 (See 44 FR 50732).

The Agency is proposing that the conventional "indicator pollutants," used for control of toxic pollutants, be treated as toxic pollutants. That is, effluent limitations will be established for them at BAT levels, and those limitations will not have to pass the BCT cost test normally required for conventional pollutants. When a permittee in a specific case can show that the waste stream does not contain any of the toxic pollutants that a BAT limitation on a conventional toxic indicator was designed to remove, then that limitation will no longer be treated as a limitation on a toxic pollutant. The technologies identified as BAT for control of toxic pllutants also afford removal of conventional pollutants to BAT levels. Whether or not the BAT effluent levels are reasonable by the BCT cost test, they are the levels of conventional pollutants that will be achieved by the BAT control technologies required for the reduction of toxic pollutants.

EPA determined the cost of reduction of BOD_5 and TSS for the selected treatment alternatives for each model plant developed for the textile industry. These costs, which are presented in Table X-1, show the estimated dollars required to remove one pound of BOD_5 plus TSS using the selected treatment alternatives. The figures are based on the total annual costs and estimated pollutant removals developed and shown in the BATEA Model Plant Control Cost Summary Tables in Section VIII.

The Agency applied the BCT methodology and concluded that BCT limitations based on multi-media filtration (BAT LEVEL 2) are reasonable for larger plants in the Woven Fabric Finishing (all subdivisions), Knit Fabric Finishing (except the Hosiery Products

TABLE X-1

COST OF REDUCTION OF BOD5 + TSS FOR THE SELECTED TREATMENT ALTERNATIVES

Subcategory	Flow (mgd)	Treatment Alternative C ($/lb of BOD5 + TSS removed)	B	D
1	0.05	-	-	0.69
1	0.11	-	-	0.38
1	0.25	-	-	0.24
2	0.6	-	2.18	1.72
2	1.5	-	1.31	1.08
2	3.0	-	0.98	0.82
3	0.11	3.69	7.22	5.48
3	0.25	2.10	3.74	3.06
4a	0.11	4.18	10.98	7.25
4a	0.6	1.40	3.29	2.39
4a	1.5	0.87	1.96	1.51
4b	0.6	1.40	3.29	2.39
4b	3.0	0.63	1.48	1.15
4b	5.0	0.51	1.27	0.96
4c	0.6	1.40	3.29	2.39
4c	1.5	0.87	1.96	1.51
4c	3.0	0.63	1.48	1.15
5a	0.25	2.27	6.08	4.06
5a	1.0	1.01	2.53	1.80
5a	3.0	0.60	1.56	1.15
5b	0.25	2.27	6.08	4.06
5b	0.6	1.34	3.47	2.39
5b	1.0	1.04	2.53	1.80
5c	0.05	-	23.11	13.52
5c	0.11	-	11.62	7.28

Alternative C = Multi-Media Filtration
Alternative B = Chemical Coagulation
Alternative D = Chemical Coagulation + Multi-Media Filtration (Chemical Coagulation + Dissolved Air Flotation for Subcategory 1)

TABLE X-1 (Cont.)

Subcategory	Flow (mgd)	Treatment Alternative C	Treatment Alternative B	Treatment Alternative D
		($/lb of BOD5 + TSS removed)		
6	0.25	1.43	2.89	2.22
6	0.6	0.85	1.65	1.31
6	1.5	0.52	0.98	0.82
7	0.25	2.96	7.07	5.02
7	0.6	1.74	4.03	2.95
7	1.0	1.31	2.94	2.22
7	1.5	1.08	2.41	1.86
8	0.11	1.78	4.41	2.99
9	0.11	-	3.87	2.55
9	0.25	-	2.03	1.43

Alternative C = Multi-Media Filtration
Alternative B = Chemical Coagulation
Alternative D = Chemical Coagulation + Multi-Media Filtration (Chemical Coagulation + Dissolved Air Flotation for Subcategory 1)

Subdivision), Carpet Finishing, Stock & Yarn Finishing, and Nonwoven Manufacturing subcategories. For larger plants in the Wool Scouring, Wool Finishing, Hosiery Products

Subdivision of Knit Fabric Finishing subcategories, BCT limitations based on chemical coagulation plus multimedia filtration (dissolved air flotation for Wool Scouring) (BAT LEVEL 4) were found to be reasonable. Using a POTW cost of $1.17 per pound of BOD_5 and TSS removed and curves plotted from the data in Table X-1, wastewater discharge volumes and production size equivalents of those volumes were determined. Plants with operating production sizes equal to or greater than those noted in the following tabulation pass the BCT "cost-reasonableness" test. Plants having smaller operating production sizes do not pass the test.

Subcategory	Production Size, kkg/yr
Wool Scouring	3,300
Wool Finishing	5,800
Woven Fabric Finishing	
Simple Processing	13,500
Complex Processing	12,200
Complex Processing Plus Desizing	9,300
Knit Fabric Finishing	
Simple Processing	7,200
Complex Processing	11,700
Hosiery Products	14,100
Carpet Finishing	9,500
Stock & Yarn Finishing	16,400
Nonwoven Manufacturing	28,300

The Agency is therefore proposing BCT effluent limitations at the BAT LEVEL 2 and BAT LEVEL 4 technologies for plants with production equal to or greater than these values and at the existing BPT limitations for plants with production less than these values. Since existing BPT effluent limitations do not exist for Nonwoven Manufacturing, the limitations for production sizes less than those in the table are based on the application of extended-aeration activated sludge (BAT Level 1). BCT effluent limitations for plants in the Low Water Use Processing Subcategory are also based on BAT Level 1 technology for all production sizes and Felted Fabric Processing Subcategory.

BCT EFFLUENT LIMITATIONS

Subcategory 1 - Wool Scouring (less than 3,300 kkg/yr production)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of raw grease wool: Maximum for any one day	Average of daily values for 30 consecutive days
BOD_5	10.6	5.3
TSS	32.2	16.1
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 1 - Wool Scouring (3,300 kkg/yr production or greater)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of raw grease wool: Maximum for any one day	Average of daily values for 30 consecutive days
BOD_5	1.5	0.9
TSS	10.9	6.3
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 2 - Wool Finishing (less than 5,800 kkg/yr production)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Average of daily values for 30 consecutive days
BOD_5	22.4	11.2
TSS	35.2	17.6
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 2 - Wool Finishing (5,800 kkg/yr production or greater)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	15.4	8.9
TSS	11.0	6.4
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 3 - Low Water Use Processing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	1.4	0.70
TSS	1.4	0.70
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 4a - Woven Fabric Finishing, Simple Processing
(less than 13,500 kkg/yr production)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	6.6	3.3
TSS	17.8	8.9
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 4a - Woven Fabric Finishing, Simple Processing
(13,500 kkg/yr production or greater)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Effluent Limitations, kg/kkg of product: Average of daily values for 30 consecutive days
BOD_5	2.7	1.6
TSS	3.4	2.0
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 4b - Woven Fabric Finishing, Complex Processing
(less than 12,200 kkg/yr production)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Effluent Limitations, kg/kkg of product: Average of daily values for 30 consecutive days
BOD_5	6.6	3.3
TSS	17.8	8.9
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 4b - Woven Fabric Finishing, Complex Processing
(12,200 kkg/yr production or greater)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Effluent Limitations, kg/kkg of product: Average of daily values for 30 consecutive days
BOD_5	5.0	2.0
TSS	4.7	2.7
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 4c - Woven Fabric Finishing, Complex Processing Plus Desizing
(less than 9,300 kkg/yr production)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	6.6	3.3
TSS	17.8	8.9
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 4c - Woven Fabric Finishing, Complex Processing Plus Desizing

(9,300 kkg/yr production or greater)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	6.6	3.3
TSS	6.2	3.6
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 5a - Knit Fabric Finishing, Simple Processing
(less than 7,200 kkg/yr production)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	5.0	2.5
TSS	21.8	10.9
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 5a - Knit Fabric Finishing, Simple Processing
(7,200 kkg/yr production or greater)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Effluent Limitations, kg/kkg of product: Average of daily values for 30 consecutive days
BOD_5	4.7	2.5
TSS	5.2	3.0
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 5b - Knit Fabric Finishing, Complex Processing
(less than 11,700 kkg/yr production)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Effluent Limitations, kg/kkg of product: Average of daily values for 30 consecutive days
BOD_5	5.0	2.5
TSS	21.8	10.9
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 5b - Knit Fabric Finishing, Complex Processing
(11,700 kkg/yr production or greater)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Effluent Limitations, kg/kkg of product: Average of daily values for 30 consecutive days
BOD_5	3.9	2.3
TSS	5.0	2.9
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 5c - Knit Fabric Finishing, Hosiery Products
(less than 14,100 kkg/yr production)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	15.0	8.7
TSS	28.0	16.0
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 5c - Knit Fabric Finishing, Hosiery Products
(14,100 kkg/yr production or greater)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	5.3	3.1
TSS	7.0	4.0
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 6 - Carpet Finishing (less than 9,500 kkg/yr production)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	7.8	3.9
TSS	11.0	5.5
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 6 - Carpet Finishing (9,500 kkg/yr production or greater)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
BOD_5	3.8	2.2
TSS	3.0	1.8
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 7 - Stock & Yarn Finishing (less than 16,400 kkg/yr production)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
BOD_5	6.8	3.4
TSS	17.4	8.7
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 7 - Stock & Yarn Finishing (16,400 kkg/yr production or greater)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
BOD_5	2.3	1.4
TSS	2.7	1.6
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 8 - Nonwoven Manufacturing (less than 28,300 kkg/yr production)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	4.3	2.5
TSS	9.3	5.4
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 8 - Nonwoven Manufacturing (28,300 kkg/yr production or greater)

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	3.3	1.9
TSS	3.3	1.9
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 9 - Felted Fabric Processing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	23.1	13.4
TSS	62.0	36.0
pH	Within the range of 6.0 to 9.0 at all times.	

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

INTRODUCTION

The basis for New Source Performance Standards (NSPS) under Section 306 of the Act is the best available demonstrated technology. New plants have the opportunity to design the best and most efficient textile manufacturing processes and wastewater treatment technologies, and, therefore, Congress directed EPA to consider the best demonstrated processes and operating methods, in-plant control measures, end-of-pipe treatment technologies, and other alternatives that reduce pollution to the maximum extent feasible, including, where practicable, a standard permitting no discharge of pollutants. A major difference between NSPS and BAT is that the Act does not require evaluation of NSPS in light of the BCT cost test.

IDENTIFICATION OF NEW SOURCE PERFORMANCE STANDARDS

The technology for New Source Performance Standards utilizes secondary biological treatment (BPT) as a basis for further improvements. BPT is defined in the earlier Development Document (1) and discussed in Sections VII and IX of this report. The in-plant control measures are the same as those described in Section VII and noted in Section IX for BAT. In new sources, greater attention can be given to these control measures in conjunction with the design of processes, equipment, and facility and in operating methods and schedules. Technologies available for NSPS include the following:

LEVEL 1 - Biological treatment (extended-aeration activated sludge),

LEVEL 2 - Biological treatment plus chemical coagulation and filtration,

LEVEL 3 - Segregate toxic pollutant waste streams from other processrelated and non-process related waste streams. Provide chemical coagulation, filtration, and carbon adsorption for toxic pollutant waste streams and biological treatment for other waste streams.

End-of-pipe treatment and stream segregation involving biological treatment plus filtration and activated carbon was evaluated technically but was not considered in establishing the NSPS level of control because it did not provide adequate control of the metallic toxic pollutants.

Based on analyses of these control options, the Agency has selected LEVEL 2 for all subcategories. For Wool Scouring, the technology includes dissolved air flotation in place of filtration becase of the nature of the solids.

NSPS EFFLUENT LIMITATIONS

Subcategory 1 - Wool Scouring

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of raw grease wool	
	Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	1.5	0.90
COD	36.3	24.6
TSS	10.9	6.3
Total Phenol	0.002	0.001
Total Chromium	0.01	0.006
Total Copper	0.01	0.006
Total Zinc	0.02	0.01
Color (ADMI units)	2400	1500
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 2 - Wool Finishing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	15.4	8.9
COD	82.4	56.2
TSS	11.0	6.4
Total Phenol	0.032	0.018
Total Chromium	0.26	0.14
Total Copper	0.26	0.14
Total Zinc	0.52	0.28
Color (ADMI units)	190	120
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 3 - Low Water Use Processing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	1.4	0.7
COD	2.8	1.4
TSS	1.4	0.7
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 4a - Woven Fabric Finishing, Simple Processing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	1.3	0.74
COD	22.8	15.5
TSS	2.4	1.4
Total Phenol	0.003	0.002
Total Chromium	0.07	0.04
Total Copper	0.07	0.04
Total Zinc	0.14	0.08
Color (ADMI units)	190	120
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 4b - Woven Fabric Finishing, Complex Processing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
BOD_5	2.4	1.4
COD	26.2	17.9
TSS	3.4	2.0
Total Phenol	0.008	0.005
Total Chromium	0.08	0.04
Total Copper	0.08	0.04
Total Zinc	0.16	0.08
Color (ADMI units)	190	120
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 4c - Woven Fabric Finishing, Complex Processing Plus Desizing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
BOD_5	3.1	1.8
COD	34.3	23.4
TSS	4.4	2.6
Total Phenol	0.008	0.005
Total Chromium	0.10	0.06
Total Copper	0.10	0.06
Total Zinc	0.20	0.11
Color (ADMI units)	190	120
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 5a - Knit Fabric Finishing, Simple Processing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product — Maximum for any one day	Effluent Limitations, kg/kkg of product — Average of daily values for 30 consecutive days
BOD_5	2.2	1.3
COD	44.4	30.3
TSS	3.7	2.1
Total Phenol	0.011	0.007
Total Chromium	0.12	0.07
Total Copper	0.12	0.07
Total Zinc	0.24	0.14
Color (ADMI units)	190	120
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 5b - Knit Fabric Finishing, Complex Processing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product — Maximum for any one day	Effluent Limitations, kg/kkg of product — Average of daily values for 30 consecutive days
BOD_5	1.8	1.1
COD	28.3	19.3
TSS	3.6	2.1
Total Phenol	0.007	0.004
Total Chromium	0.08	0.04
Total Copper	0.08	0.04
Total Zinc	0.15	0.08
Color (ADMI units)	190	120
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 5c - Knit Fabric Finishing, Hosiery Products

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
BOD_5	5.3	3.1
COD	47.7	32.5
TSS	7.0	4.0
Total Phenol	0.006	0.003
Total Chromium	0.06	0.03
Total Copper	0.06	0.03
Total Zinc	0.12	0.07
Color (ADMI units)	190	120
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 6 - Carpet Finishing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
BOD_5	1.8	1.0
COD	16.4	11.2
TSS	2.2	1.3
Total Phenol	0.007	0.004
Total Chromium	0.04	0.02
Total Copper	0.04	0.02
Total Zinc	0.08	0.05
Color (ADMI units)	190	120
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 7 - Stock & Yarn Finishing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	1.1	0.63
COD	17.0	11.6
TSS	1.9	1.1
Total Phenol	0.008	0.005
Total Chromium	0.09	0.05
Total Copper	0.09	0.05
Total Zinc	0.18	0.10
Color (ADMI units)	190	120
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 8 - Nonwoven Manufacturing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product: Maximum for any one day	Average of daily values for 30 consecutive days
BOD5	1.5	0.88
COD	27.3	18.6
TSS	2.3	1.4
Total Phenol	0.001	0.0006
Total Chromium	0.04	0.02
Total Copper	0.04	0.02
Total Zinc	0.07	0.04
Color (ADMI units)	190	120
pH	Within the range of 6.0 to 9.0 at all times.	

Subcategory 9 - Felted Fabric Processing

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
BOD_5	8.1	4.7
COD	78.5	53.5
TSS	15.7	9.1
Total Phenol	0.024	0.014
Total Chromium	0.19	0.11
Total Copper	0.19	0.11
Total Zinc	0.38	0.21
Color (ADMI units)	190	120
pH	Within the range of 6.0 to 9.0 at all times.	

METHODOLOGY USED TO DEVELOP NSPS EFFLUENT LIMITATIONS

The effluent limitations for NSPS were developed in a building block fashion by engineering analysis similar to that used for BAT. Because of the variety of processes and equipment available within subcategories, no specific in-plant control measures or operating methods were included in establishing the limitations; although, waste stream segregation was considered in LEVEL 3. Both full-scale and pilot-scale treatability data were used in developing the limitations. Using the median BPT effluent concentration values for the conventional and non-conventional pollutants (Methodology Section IX and Table V-9) as a base, factors for variability (Table IX-1) and treatment performance (Table IX-3) were applied to arrive at 30-day average and maximum day concentrations for each subcategory. The concentrations were converted to mass loadings (kg/kkg of product) by incorporating the median water usage values for each subcategory (Table V-1). The methodology is essentially the same as that previously described in Section IX for the BAT limitations.

While it is recognized that improvements are available to new sources in terms of both raw wastewater concentrations and water usage rates, there is no available information by which to quantify such improvements for typical new sources in general. The use of median, rather than average, values does, however, reflect generally better practices by reducing the influence of extremely high individual values.

REGULATED POLLUTANTS

The non-toxic, non-conventional pollutants, the toxic pollutants, and the "indicator pollutant" regulated under NSPS are the same as those regulated under BAT. One exception is pH, which is not regulated under BAT. These are discussed in Section IX of this report.

SIZE, AGE, PROCESSES EMPLOYED, LOCATION OF FACILITIES

The aspects of size, age, processes employed, and location for the subcategories discussed for BAT apply to NSPS. One aspect related to age of new sources should be noted. It is not unusual for existing textile mills to incorporate some old equipment moved from old facilities into newer mills. This practice can be expected to continue to some degree and will tend to limit some new sources in the incorporation of in-plant control measures to achieve NSPS.

ENGINEERING ASPECTS OF NEW SOURCE PERFORMANCE STANDARDS

In designing new mills in the textile industry, the full spectrum of available in-plant controls, process modifications, and equipment selections should be evaluated in order that end-of-pipe treatment technologies will be of minimal life-cycle cost, maximum effectiveness, and as free as possible of operational problems. Measures to minimize all environmental degradation should be considered so that the impact of possible future regulation will be lessened. A careful assessment of the in-plant controls, process modifications, and operating methods together with the manufacturing goals for the new facility should permit planners to realize substantial benefits.

At this time, there are many in-plant controls in use in at least a few mills that have not been applied across the industry. As noted in Section VII, the variety among mills makes complete utilization of all such measures at an individual mill impossible. There are also some in-plant controls and new manufacturing methods that are currently being researched. Some of these involve new equipment developments before they can be implemented at full-scale. These steps are not a new trend in the textile industry but are part of the normal evolutionary process that is common to most industries. It is expected that these changes will continue and that more emphasis will be placed on changes that reduce the release of environmental pollutants. While these improvements can be predicted generally, it is not feasible to make accurate predictions that pinpoint specific gains in specific subcategories.

Since the NSPS limitations apply immediately upon promulgation, the benefits of possible future improvements cannot be included. Instead, best demonstrated technology that is currently available must be used as the base. The potential benefits of such manufacturing changes as solvent (non-aqueous) processing or treatment by powdered activated carbon or steam stripping have not yet been demonstrated to be generally available to the textile industry.

Zero Discharge

At this time, zero discharge of pollutants is not technically feasible for the Textile Mills Point Source Category. Many mills are moving to conserve water through reuse, but there are limitations dictated by product quality and production schedules. Eventually, the water must be discharged due to accumulation of dyes, dissolved salts, and other chemicals that would interfere with processing mechanisms if the water were used again. It is true that a limited number of textile mills have been able to eliminate discharges from one or more of their finishing operations. These have been investigated and found to be unique situations, and similar systems cannot be implemented by all other mills in the same subcategory.

For the foreseeable future, the textile industry will have to use end-ofpipe treatment, rather than zero discharge, to control the release of wastewater pollutants.

End-of-Pipe Treatment

The end-of-pipe treatment technologies that are currently available to new sources include biological treatment, chemical coagulation, and filtration. These are discussed in Section IX and that information applies also to new sources. The discussion of sludge management programs and control of high levels of color presented in Section IX applies here also. Granular activated carbon is included in LEVEL 3 as an alternative that reduced the potential for release of some organic toxic pollutants to the atmosphere by air stripping in the biological treatment system. The overall benefits of this level of control are relatively small compared to the associated financial and energy expenditures, and this level was not selected as the basis for the NSPS effluent limitations.

Segregation of Waste Streams

Segregation of waste streams was included in the model new source plants in developing estimated costs for the LEVEL 3 control technology. While the analyses indicated that segregation was not cost-effective for other levels of control, this in-plant measure should be included in the evaluation of alternatives carried out in designing new sources. The cost analyses used in this report necessarily included several assumptions about relative waste flows originating from various operations in textile manufacturing. These flows vary between and within subcategories.

Toxic pollutants are believed to be normally present at higher concentrations in wastes from such operations as solvent scouring, dyeing and rinsing, functional finishing, and laboratory testing. Such operations as bleaching, mercerizing, scouring, and fulling should normally generate only very limited quantities of toxic pollutants. The presence of toxic pollutants in some waste streams may be controlled by substitutions for certain preservatives, coatings, and additives.

If the toxic pollutants can be isolated into one relatively smaller and more concentrated waste stream, more effective treatment should be possible at reduced costs compared to treating the entire mill waste stream to the same level of control. An additional benefit of segregation is that the toxic pollutants would be associated with only part of the sludge generated by the mill wastewater treatment systems. If this sludge is classified as hazardous waste, the associated processing and disposal costs would be reduced. The reduction of the air stripping potential, as noted previously in this section, is another possible benefit of segregation.

Segregation of waste streams is not now widely practiced in the textile industry. The technical and economic feasibility of this approach for an individual new source will require a careful analysis of all benefits and limitations, including some potential loss of manufacturing flexibility within the mill. The preliminary analyses used in this study do not provide a basis for a decision for or against the incorporation of segregated drains and treatment systems in a new source. Much site-specific data are required in order to reach such decisions.

NONWATER QUALITY ENVIRONMENTAL IMPACT

The nonwater quality environmental impacts associated with the NSPS effluent limitations are the same as those associated with the BAT effluent limitations, as discussed in Section IX.

TOTAL COST OF APPLICATION

Based on the cost information in Section VIII, the Agency estimates that investment costs for a new source to comply with the NSPS limitations, depending on subcategory, will range between 3 and 11 percent of the book value of fixed assets of the facility. Annualized costs are estimated to range between 0.9 and 4.4 percent of total sales. Implementation of NSPS will reduce the discharge of conventional, non-conventional, and toxic pollutants expected in the wastewaters of new sources to reasonably low levels with a high degree of confidence.

GUIDANCE TO ENFORCEMENT PERSONNEL

Chromium, copper, and zinc are metallic toxic pollutants specifically regulated by BAT. Antimony, arsenic, cadmium, lead, mercury, nickel, selenium, and silver are metallic toxic pollutants that were typically identified at low concentrations in textile plant raw and treated effluents but, because of their general nature, common usage, and frequency of detection, may be a problem at some textile mills. It is recommended that EPA regional, state, and municipal enforcement personnel investigate the presence of these metals and determine their levels. The following tabulation provides the average BPT effluent concentrations of these pollutants based on the results of the field sampling program and offers guidance as to recommended allowable discharge levels. These levels should be used to determine whether additional effluent limitations are appropriate for individual direct dischargers.

Metal	Typical Concentration, ug/l
Antimony	100
Arsenic	80
Cadmium	30
Lead	60
Mercury	0.4
Nickel	80
Selenium	40
Silver	40

SECTION XII

PRETREATMENT STANDARDS FOR EXISTING SOURCES

INTRODUCTION

The effluent limitations that must be achieved by existing sources in the textile industry that discharge into a publicly owned treatment works (POTW) are termed pretreatment standards. Section 307(b) of the Act requires EPA to promulgate pretreatment standards for existing sources (PSES) to prevent the discharge of pollutants that pass through, interfere with, or are otherwise incompatible with the operation of POTW. The Clean Water Act of 1977 adds a new dimension by requiring pretreatment for pollutants, such as heavy metals, that limit POTW sludge management alternatives, including the beneficial use of sludges on agricultural lands. The legislative history of the 1977 Act indicates that pretreatment standards are to be technology-based, analagous to the best available technology for removal of toxic pollutants. The general pretreatment regulations (40 CFR Part 403), which served as the framework for these proposed pretreatment regulations for the textile industry, can be found at 43 FR 27736-27773 (June 26, 1978).

Consideration was also given to the following in establishing the pretreatment standards:

- o Plant size, age of equipment and facilities, processes employed, and process changes;
- o The engineering aspects of the application of pretreatment technology and its relationship to POTW;
- o Nonwater quality environmental impact (including energy requirements); and
- o The total cost of application of technology in relation to the effluent reduction and other benefits to be achieved from such application.

Pretreatment standards must reflect effluent reduction achievable by the application of the best available pretreatment technology. This may include primary treatment technology as used in the industry and in-plant control measures when such are considered to be normal practice within the industry.

A final consideration is the determination of economic and engineering reliability in the application of the pretreatment technology. This must be determined from the results of demonstration projects, pilot plant experiments, and most preferably, general use within the industry.

IDENTIFICATION OF PRETREATMENT STANDARDS FOR EXISTING SOURCES

Most existing indirect dischargers in the textile industry provide no end-of-pipe treatment other than that required to comply with the prohibitive discharge limitations, namely, to eliminate the discharge of gross suspended solids, slug loads, extreme pH values, and explosive wastes. Some mills, however, have implemented more extensive treatment in order to comply with local sewer use ordinances. As with direct dischargers, the use of in-plant control measures varies widely. Until recently, the implementation of such measures was usually prompted more by economic factors than by considerations of water pollution control. In the future, in-plant control measures should be carefully evaluated by indirect dischargers because they will permit these mills to comply with the PSES effluent limitations without the installation of end-of-pipe treatment technologies. No specific in-plant measures were considered in establishing the PSES limitations, however, because of the wide diversity among textile mills.

End-of-Pipe Treatment Technology

LEVEL 1 - CURRENT LEVEL OF PRETREATMENT - Preliminary treatment; screening, equalization, and/or neutralization as necessary for compliance with prohibitive discharge provisions

LEVEL 2 - Preliminary treatment plus chemicl coagulation

LEVEL 3 - Preliminary treatment plus chemical coagulation and filtration

More sophisticated treatment levels involving activated carbon and ozone added to the above levels were evaluated technically but were not considered because they are too costly relative to the resulting benefits.

Based on analyses of these control options, the Agency has selected LEVEL 2 as the basis for PSES effluent limitations for all subcategories. For Wool Scouring, the technology additionally includes dissolved air flotation.

The current level of pretreatment, with appropriate in-plant control measures, will permit many mills to comply with the PSES effluent limitations without providing additional treatment levels.

PSES EFFLUENT LIMITATIONS

Subcategory 1 - Wool Scouring

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of raw grease wool Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.01	0.006
Total Copper	0.01	0.006
Total Zinc	0.02	0.012

Subcategory 2 - Wool Finishing

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are povided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.26	0.14
Total Copper	0.26	0.14
Total Zinc	0.52	0.28

Subcategory 3 - Low Water Use Processing

These plants are required to comply with the general pretreatment regulations found at 43 FR 27736-27773 (June 26, 1978).

Subcategory 4a - Woven Fabric Finishing, Simple Processing

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.07	0.04
Total Copper	0.07	0.04
Total Zinc	0.14	0.08

Subcategory 4b - Woven Fabric Finishing, Complex Processing

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.08	0.04
Total Copper	0.08	0.04
Total Zinc	0.16	0.08

Subcategory 4c - Woven Fabric Finishing, Complex Processing Plus Desizing

Pollutant or Pollutant Property	Effluent Limitations, mg/l	
	Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.10	0.06
Total Copper	0.10	0.06
Total Zinc	0.20	0.11

Subcategory 5a - Knit Fabric Finishing, Simple Processing

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.12	0.07
Total Copper	0.12	0.07
Total Zinc	0.24	0.14

Subcategory 5b - Knit Fabric Finishing, Complex Processing

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	 Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	 Average of daily values for 30 consecutive days
Total Chromium	0.08	0.04
Total Copper	0.08	0.04
Total Zinc	0.15	0.08

Subcategory 5c - Knit Fabric Finishing, Hosiery Products

Pollutant or Pollutant Property	Effluent Limitations, mg/l	
	Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.06	0.03
Total Copper	0.06	0.03
Total Zinc	0.12	0.07

Subcategory 6 - Carpet Finishing

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	 Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	 Average of daily values for 30 consecutive days
Total Chromium	0.04	0.02
Total Copper	0.04	0.02
Total Zinc	0.08	0.05

Subcategory 7 - Stock & Yarn Finishing

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	 Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.09	0.05
Total Copper	0.09	0.05
Total Zinc	0.18	0.10

<u>Subcategory 8 - Nonwoven Manufacturing</u>

Pollutant or Pollutant Property	Effluent Limitations, mg/l	
	Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.04	0.02
Total Copper	0.04	0.02
Total Zinc	0.07	0.04

Subcategory 9 - Felted Fabric Processing

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.19	0.11
Total Copper	0.19	0.11
Total Zinc	0.38	0.21

METHODOLOGY USED TO DEVELOP PSES EFFLUENT LIMITATIONS

The rationale and method used in developing the PSES effluent limitations are described below.

Rationale

The basic concept used in developing the PSES effluent limitations was that the mill pretreatment system plus the treatment provided by the POTW should be equivalent to BAT in terms of protection of the receiving waters. In order words, indirect dischargers should not be permitted to discharge toxic pollutants that pass through POTW to any greater extent than that permitted mills discharging directly to receiving waters.

The selected technology level for BAT in most of the subcategories is biological treatment plus filtration. For the purposes of this development, it is assumed that the treatment provided by the POTW provides biological treatment or its equivalent. The level of pretreatment should be equivalent to filtration in order that it plus the POTW equal BAT. The suspended solids levels in the raw wastewaters from most textile mills, even with proper preliminary treatment, are too high for effective direct treatment by filtration and an alternative technology must be considered. Chemical coagulation provides such an alternative. This process is aimed primarily at the same target pollutants as filtration, namely, suspended solids. Chemical coagulation provides the additional benefits of being capable of effecting higher removals of non-biodegradable COD, metals, and color than is generally achievable by filtration.

The most commonly reported problems experienced by POTW receiving textile mill discharges relate to gross solids and slug discharges. These should be controlled by enforcement of the prohibitive waste discharge provisions of the general pretreatment regulations. Few POTW report upsets or interferences associated with the constitutive characteristics of textile mill wastes beyond those caused by overloading and discharge fluctuations. However, there are inadequate data available by which to determine the extent of pass-through or contamination of POTW sludges by textile mill waste constituents. It is suspected that this last area will be found to be the major area of concern for those POTW that are impacted by toxic pollutants in textile mill wastes, and that the metals will be the most significant contaminants. For this reason, the three metals found in relatively high concentrations in the raw wastes from some textile mills, namely, chromium, copper, and zinc, are regulated by the PSES effluent limitations. As noted in Section IX, local authorities should assure themselves that the levels of other metallic toxic pollutants are also adequately controlled by the textile mills within their jurisdictions.

Method

The Agency established the effluent limitations by engineering analysis of the degrees of control achieved in treating metal-bearing wastewaters by chemical coagulation in other industries. The literature clearly indicates that well operated chemical treatment systems can consistently achieve the specified effluent limitations. A separate factor that was also recognized is that the results of the screening and verification sampling programs indicated that the average raw waste concentrations of the three regulated metals were below the effluent limitations. This tends to support the contention that most indirect dischargers will not require additional end-of-pipe treatment beyond the current level of pretreatment.

SIZE, AGE, PROCESSES EMPLOYED, LOCATION OF FACILITIES

As discussed in Section IX, the factors of size, age, and location do not affect the control technology that can be effectively applied to direct discharging textile mills in each subcategory. Process factors are already included in the subcategorization. Indirect discharge textile mills are indistinguishable from direct dischargers in terms of age and processes employed. They are distributed in the same states as the direct discharge mills and, except for their being within POTW service areas, location does not play a role in determining the availability of the treatment technologies. The average size of the indirect discharge mills is approximately half that of the average direct discharge mill in terms of daily discharge volume, although the range of sizes is the same for both groups. Size is not a factor in determining the technology that can be applied effectively. Size relative to the size of the POTW may be of concern, however, and more stringent local control may be required where textile wastes constitute a major fraction of the influent to the POTW.

ENGINEERING ASPECTS OF PRETREATMENT STANDARDS FOR EXISTING SOURCES

As noted previously, few existing indirect dischargers in the textile industry provide any significant end-of-pipe treatment. Those that are unable to comply with the PSES effluent limitations through in-plant control measures will have to develop new programs and face an array of unfamiliar problems. It is important that adequate planning and evaluation of alternatives be carried out so that the program developed will be truly effective, economic, and free of avoidable operating and maintenance problems.

The treatment system should be the result of testing and careful analysis of several alternative approaches. The selection for individual mills should not be based solely on the findings developed in this report.

For example, some mills may find that biological treatment and/or filtration provides the best treatment technology. Some of the advantages and limitations of these processes are discussed in Sections VII, VIII, and IX. Likewise, decisions about the components of the preliminary treatment system should be based upon analysis of the mill's wastewater characteristics, the site-specific conditions, and the overall goals of the wastewater treatment program. An important element in the planning should be the sludge management program. Sludges from chemical treatment are often more difficult to dewater than those from biological systems, and if the sludge is classified a hazardous waste, the requirements of the Resource Conservation and Recovery Act (RCRA) regulations regarding generation, storage, transportation, and disposal will have to be considered.

Little work has been done to date on the treatment of textile wastes by other than biological processes. Research should be carried out to investigate various processes and optimal operating modes for various ranges of waste characteristics. Chemical coagulation is a versatile process that has been widely applied to a spectrum of industrial wastes. Despite this, there is often a fine line between success and failure of this process and the optimal chemical conditions can be determined only by experimental means. Alum has seen use in the textile industry for treating the effluents from biological systems but is less effective than lime and iron salts for controlling metals. These latter chemicals tend to precipitate the dissolved metals as well as coagulate the suspended solids.

In summary, the treatment system and waste control program should be designed and operated to solve the problems peculiar to the individual mill applied.

NONWATER QUALITY ENVIRONMENTAL IMPACT

The discussion of nonwater quality environmental impact for direct dischargers presented in Section IX also applies to indirect dischargers. The implementation of PSES effluent limitations will result in improvement in the quality of some POTW sludges, but it will also create new sources of sludges at the mill that will require monitoring to insure that they are properly managed.

TOTAL COST OF APPLICATION

Based on the cost information in Section VIII, the total investment cost for all indirect dischargers is estimated to be $38 million with associated total annualized cost of $19 million. The costs are relatively low because only about 107 mills of the indirect dischargers may have to apply the full level of end-of-pipe treatment control. The other mills either have sufficient treatment technology in place (78) or do not exceed the limitations due to elimination of the regulated pollutants from raw materials (741). The number of mills which can meet PSES through substitution of raw materials was estimated by extrapolation from data available for 47 indirect dischargers.

Implementation of PSES, along with the treatment provided by a POTW, would reduce the wastewater discharge of the conventional pollutants, non-conventional pollutants, and toxic pollutants that are found in textile mill wastewaters to levels equivalent to those achieved by BAT with a high degree of confidence.

GUIDANCE TO ENFORCEMENT PERSONNEL

Chromium, copper, and zinc are metallic toxic pollutants specifically regulated by PSES. Antimony, arsenic, cadmium, lead, mercury, nickel, selenium, and silver are metallic toxic pollutants that were typically identified at low concentrations in textile plant raw wastes but, because of their general nature, common usage, and frequency of detection, may be a problem at some textile mills. It is recommended that EPA regional, state, and municipal enforcement personnel investigate the presence of these metals and determine their levels. The following tabulation provides the average raw waste concentrations of these pollutants based on the results of the field sampling program and offers guidance as to recommended allowable discharge levels. These levels should be used to determine whether additional effluent limitations are appropriate for individual indirect dischargers.

Metal	Typical Concentration, ug/l
Antimony	100
Arsenic	80
Cadmium	30
Lead	100
Mercury	1
Nickel	100
Selenium	40
Silver	50

While national COD standards for PSES have not been determined to be appropriate, municipal enforcement personnel should be cognizant of the high COD levels discharged by many textile mills. The COD consists of a biodegradable fraction that is effectively treated in POTW and a refractory fraction that is not effectively treated in most POTW. The industry has the capability of substituting for materials having high BOD with materials having relatively low BOD but high COD. One example is the substitution of synthetic sizing agents such as PVA and CMC for starch. It is recommended that state and municipal enforcement personnel investigate the level of COD being discharged by textile mills to POTW and the removal effectiveness of the COD at the POTW. The following tabulation provides typical COD values in the raw untreated wastewater for each subcategory of the industry and the recommended COD effluent levels from biological treatment systems similar to POTW. Enforcement personnel should use this information as guidance to determine whether individual pretreatment standards for COD are appropriate for textile mills discharging to a particular POTW.

Subcategory	Concentration, mg/l Typical Raw Waste	Typical Effluent After Biological Treatment
Wool Scouring	7,000	2,600
Wool Finishing	600	240
Low Water Use Processing	700	220
Woven Fabric Finishing		
Simple Processing	900	240
Complex Processing	1,100	250
Complex Plus Desizing	1,200	250
Knit Fabric Finishing		
Simple Processing	870	270
Complex Processing	800	280
Hosiery Products	1,370	570
Carpet Finishing	1,190	290
Stock & Yarn Finishing	680	140
Nonwoven Manufacturing	550	560
Felted Fabric Processing	2,400	300

SECTION XIII

PRETREATMENT STANDARDS FOR NEW SOURCES

INTRODUCTION

Section 307(c) of the Act requires EPA to promulgate Pretreatment Standards for New Sources (PSNS) at the same time that it promulgates NSPS. New indirect dischargers, like new direct dischargers, have the opportunity to incorporate the best available demonstrated technologies including process changes, in-plant controls, and end-of-pipe treatment technologies, and to use plant site selection to insure adequate treatment system installation.

IDENTIFICATION OF PRETREATMENT STANDARDS FOR NEW SOURCES

The in-plant control measures, process selections, operating methods, and end-of-pipe treatment technologies available to new indirect discharge sources for complying with PSNS effluent limitations are the same as those for new direct discharge sources in the textile industry. While no specific in-plant control measures are required, the full spectrum of such measures should be carefully evaluated for potential application during the planning and design phases for the new manufacturing facility in order to reduce the extent and costs of end-of-pipe treatment systems, sludge management programs, and sewer use charges.

End-of-Pipe Treatment Technology

LEVEL 1 - CURRENT LEVEL OF PRETREATMENT - Pretreatment treatment; screening, equalization, and/or neutralization as necessary for compliance with prohibitive discharge provisions

LEVEL 2 - Preliminary treatment of all wastes plus segregation and chemical coagulation and filtration of toxic pollutant waste streams

LEVEL 3 - Preliminary treatment of all wastes plus segregation and chemical coagulation, filtration, and carbon adsorption of toxic pollutant waste streams

Treatment levels involving ozone in place of activated carbon adsorption were evaluated technically but were not considered because they are too costly and energy-intensive relative to the resulting benefits.

Based on analyses of these control options, the Agency has selected LEVEL 2 as the basis for PSNS effluent limitations for all subcategories.

PSNS EFFLUENT LIMITATIONS

Subcategory 1 - Wool Scouring

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of raw grease wool Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.01	0.006
Total Copper	0.01	0.006
Total Zinc	0.02	0.012

Subcategory 2 - Wool Finishing

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.26	0.14
Total Copper	0.26	0.14
Total Zinc	0.52	0.28

<u>Subcategory 3 - Low Water Use Processing</u>

New plants in this subcategory are required to comply with the general pretreatment regulations found at 43 FR 27736-27773 (June 26, 1978).

<u>Subcategory 4a - Woven Fabric Finishing, Simple Processing</u>

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.07	0.04
Total Copper	0.07	0.04
Total Zinc	0.14	0.08

Subcategory 4b - Woven Fabric Finishing, Complex Processing

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.08	0.04
Total Copper	0.08	0.04
Total Zinc	0.16	0.08

Subcategory 4c - Woven Fabric Finishing, Complex Processing Plus Desizing

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.10	0.06
Total Copper	0.10	0.06
Total Zinc	0.20	0.11

Subcategory 5a - Knit Fabric Finishing, Simple Processing

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.12	0.07
Total Copper	0.12	0.07
Total Zinc	0.24	0.14

<u>Subcategory 5b - Knit Fabric Finishing, Complex Processing</u>

Pollutant or Pollutant Property	Effluent Limitations, mg/l	
	Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.08	0.04
Total Copper	0.08	0.04
Total Zinc	0.15	0.08

Subcategory 5c - Knit Fabric Finishing, Hosiery Products

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	 Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	 Average of daily values for 30 consecutive days
Total Chromium	0.06	0.03
Total Copper	0.06	0.03
Total Zinc	0.12	0.07

Subcategory 6 - Carpet Finishing

Pollutant or Pollutant Property	Effluent Limitations, mg/l	
	Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.04	0.02
Total Copper	0.04	0.02
Total Zinc	0.08	0.05

Subcategory 7 - Stock & Yarn Processing

Pollutant or Pollutant Property	Effluent Limitations, mg/l	
	Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.09	0.05
Total Copper	0.09	0.05
Total Zinc	0.18	0.10

Subcategory 8 - Nonwoven Manufacturing

Pollutant or Pollutant Property	Effluent Limitations, mg/l	
	Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product	
	Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.04	0.02
Total Copper	0.04	0.02
Total Zinc	0.07	0.04

Subcategory 9 - Felted Fabric Processing

Pollutant or Pollutant Property	Effluent Limitations, mg/l Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.90	0.50
Total Copper	0.90	0.50
Total Zinc	1.80	1.00

In cases when POTW find it necessary to impose mass effluent limitations, the following equivalent mass limitations are provided as guidance:

Pollutant or Pollutant Property	Effluent Limitations, kg/kkg of product Maximum for any one day	Average of daily values for 30 consecutive days
Total Chromium	0.19	0.11
Total Copper	0.19	0.11
Total Zinc	0.38	0.21

METHODOLOGY USED TO DEVELOP PSNS EFFLUENT LIMITATIONS

The rationale and method used in developing the PSNS effluent limitations are described below.

Rationale

The basic rationale used in developing the PSES effluent limitations also applies to the PSNS limitations. However, with the greater use of in-plant control measures and the segregated stream concept, the concentrations of conventional, non-conventional, and toxic pollutants in the toxic pollutant waste stream will be significantly higher than in the combined waste stream at an existing source. In order to insure the control of these higher levels of toxic pollutants as completely as possible and thereby prevent pass-through at POTW and minimize contamination of POTW sludges and other residues, new indirect dischargers are required to perform an additional level of control in the form of filtration. This additional treatment will better insure the removal of the regulated and non-regulated toxic pollutants as well as reduce the levels of conventional and non-conventional pollutants to levels safe for handling at POTW.

Method

The method used to develop the PSNS effluent limitations was the same as that used for the PSES limitations. As with PSES, no allowance was included for possible future reductions in raw waste loads because these potential reductions cannot be quantified at this time and also because the PSNS limitations become effective immediately upon promulgation.

SIZE, AGE, PROCESSES EMPLOYED, LOCATION OF FACILITIES

The factors of size, age of equipment, processes employed, and location of the new facilities that are discussed in Sections IX, XI, and XII apply to new indirect discharge sources. These factors do not play any significant roles in the selection or effectiveness of the control technologies and are not included in establishing the PSNS effluent limitations.

ENGINEERING ASPECTS OF PRETREATMENT STANDARDS FOR NEW SOURCES

The discussions of preliminary treatment, chemical coagulation, and filtration, including sludge management programs, presented in Sections IX, XI, and XII pertain equally well to new indirect discharge sources in the textile industry. Segregation of waste streams offers advantages in waste treatment and sludge management that should be explored fully in the development of new textile mills. If non-process wastewaters and selected process-related waste streams can be discharged to the POTW with only preliminary treatment, savings will obviously accrue compared to pretreatment of the total mill waste discharge. As noted in Section XI, however, the technical and economic feasibility of providing segregated waste lines in new textile mills remains to be investigated. Site-specific factors will play an important role in most cases.

In summary, while some further study is necessary to optimize the effectiveness of the available and possible future end-of-pipe treatment technologies, much work is indicated in the areas of in-plant controls, including segregated waste streams, in order to minimize the cost and impact of the PSNS effluent limitations.

NONWATER QUALITY ENVIRONMENTAL IMPACT

The areas of nonwater quality environmental impact discussed in Sections IX, XI, and XII apply to PSNS.

TOTAL COST OF APPLICATION

Based on the cost information in Section VIII, the Agency estimates that investment costs for a new source to comply with the PSNS limitations, depending on subcategory, will range between 1 and 8 percent of the book value of fixed assets of the facility. Annualized costs are estimated to range between 0.4 and 3.0 percent of total sales. Implementation of PSNS, along with the treatment provided by a POTW, will reduce the discharge of conventional, non-conventional, and toxic pollutants expected to be in the wastewaters of new sources to levels equivalent to those achieved by NSPS with a high degree of confidence.

GUIDANCE TO ENFORCEMENT PERSONNEL

Chromium, copper, and zinc are metallic toxic pollutants specifically regulated by PSES. Antimony, arsenic, cadmium, lead, mercury, nickel, selenium, and silver are metallic toxic pollutants that were typically identified at low concentrations in textile plant raw wastes but, because of their general nature, common usage, and frequency of detection, may be a problem at some textile mills. It is recommended that EPA regional, state, and municipal enforcement personnel investigate the presence of these metals and determine their levels. The following tabulation provides the average raw waste concentrations of these pollutants based on the results of the field sampling program and offers guidance as to recommended allowable discharge levels. These levels should be used to determine whether additional effluent limitations are appropriate for individual indirect dischargers.

Metal	Typical Concentration, ug/l
Antimony	100
Arsenic	80
Cadmium	30
Lead	100
Mercury	1
Nickel	100
Selenium	40
Silver	50

While national COD standards for PSES have not been determined to be appropriate, municipal enforcement personnel should be cognizant of the high COD levels discharged by many textile mills. The COD consists of a biodegradable fraction that is effectively treated in POTW and a refractory fraction that is not effectively treated in most POTW. The industry has the capability of substituting for materials having high BOD with materials having relatively low BOD but high COD. One example is the substitution of synthetic sizing agents such as PVA and CMC for starch. It is recommended that state and municipal enforcement personnel investigate the level of COD being discharged by textile mills to POTW and the removal effectiveness of the COD at the POTW. The following tabulation provides typical COD values in the raw untreated wastewater for each subcategory of the industry and the recommended COD effluent levels from biological treatment systems similar to POTW. Enforcement personnel should use this information as guidance to determine whether individual pretreatment standards for COD are appropriate for textile mills discharging to a particular POTW.

	Concentration, mg/l	
Subcategory	Typical Raw Waste	Typical Effluent After Biological Treatment
Wool Scouring	7,000	2,600
Wool Finishing	600	240
Low Water Use Processing	700	220
Woven Fabric Finishing		
Simple Processing	900	240
Complex Processing	1,100	250
Complex Plus Desizing	1,200	250
Knit Fabric Finishing		
Simple Processing	870	270
Complex Processing	800	280
Hosiery Products	1,370	570
Carpet Finishing	1,190	290
Stock & Yarn Finishing	680	140
Nonwoven Manufacturing	550	560
Felted Fabric Processing	2,400	300

SECTION XIV

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SECTION XVI

GLOSSARY

Animal Hair Fibers

Fibers obtained from animals for purposes of weaving, knitting, or felting into fabric; some animal fibers are alpaca, angora goat hair, camel hair, cashmere, cow hair, extract wool, fur, horse hair, llama, mohair, mungo, noil, shoddy, silk, vicuna, and wool.

Anti-static Agents

Functional finishes applied to fabric to overcome deleterious effects of static electricity. Compounds commonly used are PVA, styrene-base resins, polyalkylene glycols, gelatine, PAA, and polyvinyl acetate.

Batch Processing

Operations which require loading of discrete amounts of material, running the process to completion, and then removing the material. This is in contrast to continuous processing in which material in rope or open width form runs without interruption through one or more processes, obviating the need for loading and unloading.

Best Available Technology Economically Achievable (BAT)

Level of technology applicable to effluent limitations to be achieved by July 1, 1984, for industrial discharges to surface waters as defined by Section 301 (b) (2) of the Federal Water Pollution Control Act, As Amended.

Best Practicable Control Technology Currently Available (BPT)

The level of technology applicable to effluent limitations to be achieved by July 1, 1977, for industrial discharges to surface waters as defined by Section 301 (b) (1) (A) of the Federal Water Pollution Control Act, As Amended.

Complex Processing

Woven or knit fabric finishing operations that may consist of fiber preparation, scouring, functional finishing, and more than one of the following processes each applied to more than five percent of total production: bleaching, dyeing, or printing.

Consent Decree

The Settlement Agreement entered into by EPA with the Natural Resources Defense Council and other environmental groups and approved by the U.S. District Court for the District of Columbia on June 7, 1976. One of the principal provisions of the Settlement Agreement was to direct EPA to consider an extended list of 65 classes of pollutants in 21 industrial categories, including Textile Mills, in the development of effluent limitations guidelines and new source performance standards.

Conventional Pollutants

Constituents of wastewater as determined by Section 304 (a) (4) of the Clean Water Act of 1977, including but not limited to, pollutants classified as biological oxygen demanding, suspended solids, fecal coliform, and pH.

Direct Discharger

An industrial discharger that introduces wastewater to a receiving body of water or land, with or without treatment by the discharger.

Effluent Limitation

A maximum amount per unit of production (or other unit) of each specific constituent of the effluent that is subject to limitation from an existing point source.

End-of-Pipe Technologies

Treatment processes used to remove or alter the objectionable constituents of the spent water from manufacturing operations.

Environmental Protection Agency - Sewage Treatment Plant (EPA-STP)

A sewage treatment plant construction cost index originating in 1957 with a base cost index of 100.

Environmental Protection Agency - Small City Conventional Treatment (EPA-SCCT)

A sewage treatment plant construction cost index originating in the 3rd Quarter, 1973, and based on a cost index of 100 for St. Joseph, Missouri.

Federal Water Pollution Control Act Amendments of 1972

Public Law 92-500 which provides the legal authority for current EPA water pollution abatement projects, regulations, and policies. The Federal Water Pollution Control Act was amended further in 1977 in legislation referred to as The Clean Water Act.

Functional Finish Chemicals

Substances applied to fabric to provide desirable properties such as wrinkle-resistance, water-repellency, flame-resistance, etc.

Greige Mills

Facilities which manufacture unfinished woven or knit goods (greige goods) for finishing at other locations. If process wastewater is generated, it is usually small in quantity.

Indirect Discharger

An industrial discharger that introduces wastewater to a publicly-owned collection system.

In-plant Control Technologies

Controls or measures applied within the manufacturing process to reduce or eliminate pollutant and hydraulic loadings of raw wastewater. Typical inplant control measures include chemical substitution, material reclamation, water reuse, water reduction, and process changes.

Internal Subcategorization

Divisions within a subcategory to group facilities that, while producing related products from similar raw materials, have differing raw waste characteristics due to the complexity of manufacturing processes employed.

Low-Water-Use Processing Mills

Establishments primarily engaged in manufacturing greige goods, laminating or coating fabrics, texturizing yarn, producing tire cord fabric, and similar activities in which cleanup is the primary water use or process water requirements are small.

National Pollutant Discharge Elimination System (NPDES)

A Federal program requiring industry and municipalities to obtain permits to discharge plant effluents to the nation's water courses.

New Source

Industrial facilities from which there is, or may be, a discharge of pollutants, and whose construction is commenced after the publication of the proposed regulations.

Non-Conventional Pollutants

Parameters selected for use in developing effluent limitation guidelines and new source performance standards which have not been previously designated as either conventional pollutants or priority pollutants.

Non-Water Quality Environmental Impact

Deleterious aspects of control and treatment technologies applicable to point source category wastes, including, but not limited to, air pollution, noise, radiation, sludge and solid waste generation, and energy usage.

Physical-Chemical Treatment

Processes that utilize physical (i.e., sedimentation, filtration, centrifugation, activated carbon, reverse osmosis, etc.) and/or chemical means (i.e., coagulation, oxidation, precipitation, etc.) to treat wastewaters.

Point Source Category

A collection of industrial sources with similar function or product, established by Section 306 (b) (1) (A) of the Federal Water Pollution Control Act, As Amended for the purpose of establishing Federal standards for the disposal of wastewater.

Pollutant Loading

Ratio of the total daily mass discharge of a particular pollutant to the total daily wet production of a mill expressed in terms of (kg pollutant)/(kkg wet production).

Pretreatment Standard

Industrial waste effluent quality required for discharge to a publicly-owned treatment works.

Product Line

Goods which are similar in terms of raw materials, method of manufacture, and/or function (e.g., scoured wool, wool goods, woven goods, knit goods, carpet, stock and yarn, nonwovens, felts, etc.).

Publicly-Owned Treatment Works (POTW)

A facility that collects, treats, or otherwise disposes of wastewaters, owned and operated by a village, town, county, authority, or other public agency.

Raw Waste Characteristics

A description of the constituents and properties of a wastewater before treatment.

Simple Processing

Woven or knit fabric finishing operations that may consist of fiber preparation, scouring, functional finishing, and one of the following processes applied to more than five percent of total production: bleaching, dyeing, or printing.

Standard Industrial Classification (SIC)

A numerical categorization scheme used by the U.S. Department of Commerce to denote segments of industry.

Standard of Performance

A maximum weight discharged per unit of production for each constituent that is subject to limitations. Standards of performance are applicable to new sources, as opposed to existing sources which are subject to effluent limitations.

Synthetics

As used in this report, synthetics refers to all man-made fibers, including those manufactured from naturally occurring raw materials (regenerated fibers). Strictly speaking, synthetic fibers are those that are made by chemical synthesis.

Toxic Pollutants

All compounds specifically named or referred to in the Consent Decree, as well as recommended specific compounds representative of the non-specific or ambiguous groups or compounds named in the agreement. This list of pollutants was developed based on the use of criteria such as known occurrence in point source effluents, in the aquatic environment, in fish, in drinking water, and through evaluations of carcinogenicity, other chronic toxicity, bioaccumulation, and persistence.

Water Usage

Ratio of the spent water from a manufacturing operation to the total wet production by the mill, expressed in terms of (liters of waste-water/day)/(kilogram of wet production/day).

Wet Processing Mills

As used in this report, it refers to all manufacturing facilities having major wet manufacturing operations. Any mill in the following manufacturing segments is a wet processing mill: Wool Scouring, Wool Finishing, Woven Fabric Finishing, Knit Fabric Finishing (including Hosiery Finishing), Carpet Finishing, Stock & Yarn Finishing, Nonwoven Manufacturing, and Felted Fabric Processing.

Wet Production

Mass of textile goods that goes through one or more major wet processes in a specified time period.

APPENDIX A

SURVEY FORMS USED IN 308 DATA REQUESTS

FIGURE A-1

TELEPHONE SURVEY FORM

Company Name ______________________________ Plant Code No. __________

Plant Name ______________________________ Letter Date __________

City ____________________ State ______ Telecon Date __________

Contact ____________________ Tele __________ Time __________

A. Plant Classification (circle one or more numbers)

Subcategory	Approx. Percent
0. Dry Operation (no process-related wastewater)	
1. Wool Scouring	______
2. Wool Finishing	______
3. Dry Processing	
a. Greige	______
b. Adhesive related	______
4. Woven Fabric Finishing	______
5. Knit Fabric Finishing	______
6. Carpet Mill	______
7. Stock & Yarn	______
8. Nonwovens	______
9. Miscellaneous (describe reverse side)	

B. Approximate Plant Capacity - (lb per day; no. of employees; large, medium, or small, etc.) ______________________________

C. Wastewater Discharge

______ Direct

______ Indirect POTW Name ______________________________

______ Other (describe reverse side)

1. Is treatment (pretreatment) provided? (circle) Yes No

   Type of Treatment (describe units in sequence reverse side)

2. Discharge volume ____________________ GPD

3. Is wastewater and/or treatment data available (circle) Yes No

4. General Quality of Data ______________________________

5. Who has data? ______________________________

D. Follow-up Questionnaire? Yes No

Check if additional information on reverse side of form. ____

FIGURE A-2

EPA INDUSTRY SURVEY
TEXTILE PLANTS: BAT-NSPS-PRETREATMENT

Please complete as many of the questionnaire items as possible. It would be most helpful if questionnaire is returned by ____________________ to:

Dr. James C. Buzzell
Sverdrup & Parcel and Associates, Inc.
800 N. 12th Blvd.
St. Louis, MO 63101
Tel: (314) 436-7600 Ext. 243 or 347

Company ______________________________ Plant ____________________

Plant Location ____

Part I - GENERAL PLANT INFORMATION

A. Please indicate method used to dispose of process-related wastewaters.

____ Direct Discharge - Discharge of treated or untreated process-related wastewaters directly to a receiving body of water.

____ Indirect Discharge - Discharge of partially treated or untreated process-related wastewaters directly to a Publicly Owned Treatment Works (POTW) via municipal sewer system.

____ Other Discharge such as septic tank, evaporation lagoon, irrigation system, etc. Please explain briefly below.

____

____

B. If your plant is a Direct or Other Discharger do you have firm plans to discharge process-related wastewater to a POTW in the future? __________

C. If your plant is an Indirect Discharger please provide as much of the following information as possible. Please contact POTW if necessary.

POTW name and location ______________________________________

POTW type (e.g. primary clarification, activated sludge, trickling filter, aerated lagoon, oxidation ditch, etc.) ____________________

POTW design flow ______________ POTW present average flow __________

If POTW has biological treatment indicate year of completion. ________

Is POTW designed specifically to treat textile wastewaters? __________

Did your plant participate directly in construction of POTW? _________

Does your plant participate directly in operation of POTW? ___________

Does your plant provide pretreatment? _____ Is it required by POTW? ____

Does POTW currently meet EPA secondary treatment requirements?

( ) Yes ( ) No ( ) Don't Know

Company ______________________

Plant ______________________

Part II - MANUFACTURING INFORMATION

A. EPA Subcategorization. Please indicate average pounds production per day. Do not include redyes; they are covered separately below.

Subcategory	lb/day	Fiber Content	lb/day
1. Wool Scouring (Raw Grease Wool)	____	Wool	____
		Cotton	____
2. Wool Dye/Finish	____	Polyester	____
3. Dry Processing		Rayon	____
Woven Greige Goods	____	Nylon	____
Knit Greige Goods	____	Acetate	____
Adhesive Products	____	Acrylic	____
Carpet Backing	____	Modacrylic	____
Other ____________	____	Other ____________	____
4. Woven Fabric Dye/Finish	____	Other ____________	____
5. Knit Fabric Dye/Finish	____	Other ____________	____
6. Carpet Dye/Finish	____	Total	____
7. Stock & Yarn Dye/Finish	____	Fiber Blends (e.g. 65% cotton/35% polyester)	
8. Nonwovens			
Mechanical Entanglement	____	____________	____
Wet Lay Process	____	____________	____
Spun Bond Process	____	____________	____
Dry Processed	____	____________	____
9. Other ____________	____		
Other ____________	____		
Total	____		

Final manufactured product(s) (e.g. sheeting, hosiery, carpet, thread, etc.) ______________________

____

Average Pounds RE-DYES per day ______________________

B. Process Wastewater. Please indicate the average gallons of process-related wastewater discharged per day. ______________ gpd.

C. Schematic. Please provide, by attachment or by sketch in the space below, a simple block diagram of your wet manufacturing processes.

Company ______________________

Plant ______________________

Part II (Cont.)

D. Production Process Information. Please indicate approximate percent of production through the following processes. Please do not include Re-dyes.

Percent	Process
____	Wool Scouring
____	Slashing: ____% Starch; ____% PVA; ____% CMC; ____% other ______
____	Weaving
____	Desizing: Type of size ______________________
____	Scouring: ____% Open width; ____% Rope Range
____	Bleaching: Bleach is ______________________
____	Mercerizing: Is caustic recovered? ( ) Yes ( ) No
____	Carbonizing
____	Stock Dyeing: ____% package (200°F); ____% package (250°F); ____% skein
____	Yarn Dyeing: ____% package (200°F); ____% package (250°F)
____	Fabric Dyeing: ____% atmospheric (200°F); ____% pressure (250°F)

Dye machines are ____% Continuous ____% Jet

____% Beam ____% Jig

____% Beck ____% Other ______________

Dye machines are ____% automated ____% manual

Dye usage. Please indicate average pounds per day or percent per day for each dye class used.

lb/day	%	Dye	lb/day	%	Dye
____	____	Acid	____	____	Naphthol
____	____	Cationic	____	____	Reactive
____	____	Developed	____	____	Sulfur
____	____	Direct	____	____	Vat
____	____	Dispersed	____	____	____________

____ Printing: Type(s) ______________________

____ Functional Finishes: Please identify types of finishes applied.

____	Crease-resistant	____	Moth-proof
____	Water-repellant	____	Mildew-resistant
____	Flame-resistant	____	Other ____________
____	Bacteriostatic	____	Other ____________

Please indicate the method(s) of disposal of concentrated dye and/or print paste wastes ______________________

Company______ ______________________

Plant______________________________

Part III- WASTEWATER TREATMENT AND IN-PLANT CONTROLS

A. Treatment or Pretreatment Information. Please indicate existing and/or proposed treatment or pretreatment steps in sequence, i.e., 1 for first unit, 2 for second unit, etc. Also please provide, by attachment or by sketch on the following page, a simple block diagram of your waste treatment system. Indicate non-process waste streams (sanitary sewage, cooling water, etc.) if separate from process waste streams and identify wastewater sampling locations.

Existing Proposed

____ ____ Screening: Type____________________ Spacing______________

____ ____ Equalization: ____Mixed Volume__________gal _______HP

____Unmixed Volume__________gal

____ ____ Neutralization:______Acid feed ______Alkali feed

Tank volume __________gal _______HP

____ ____ Primary Sedimentation:

No. of units______ Depth______________ft

Dimensions____

____ ____ Aeration:

No. of units______ Volume under aeration___________gal

Total aeration HP_______ Detention period___________hr

Aerators are ____Surface ____Diffused ____Other

Typical MLSS___________________ mg/l

____ ____ Secondary Sedimentation:

No. of units______ Depth_____________ft

Dimensions____

Is sludge returned to aeration basins? ____yes ____no

____ ____ Unaerated Ponds:

No. of units______ Total volume___________________gal

____ ____ Other: (If using other steps, e.g., skimming, flotation, coagulation, trickling filters, nutrient addition, disinfection, tertiary processes, etc., please describe.)

____

____

____

Approx. amount of sludge generated daily? (specify units)______________

Is sludge treated? ______ If so, please describe process(es)______________

____

Please describe ultimate sludge disposal method.______________________

____

If removal is by outside contractor give approximate cost/ton $____________

Company ______________________

Plant ______________________

Part III (Cont.)

Note: Use this space to provide block diagram of your treatment or pre-treatment system.

B. Studies. Please briefly describe any water pollution abatement studies conducted by your plant during the past three years.

____

____

____

C. In-Plant Control Information. Does your plant practice in-plant production process control such as water reuse, water recycle, material reclamation, chemical substitution, etc? ___yes ___no
If so, please use the table below and estimate the reduction in water usage and/or pollutant quantities for each control; if possible give an estimate of the net cost for each control.

Control Type	Year Installed	Approx. Cost	Flow Reduction	BOD5 Reduction	COD Reduction

Company ______________________

Plant ______________________

Part IV - WASTEWATER DATA

Please provide representative monitoring data that characterize the raw (untreated) and treated wastewater discharged. Parameters of interest are flow rate, BOD5, COD, TSS, sulfide, phenol, chromium and any other priority pollutant listed in Part VI, for which data are available. Submit data sheets as illustrated on the following page or submit copies of monitoring reports. Data for 1976 is most desirable. Please indicate approximate production levels that correspond to data provided; also indicate sampling technique (grab, 24-hour composite, flow-proportional composite, time composite, etc.).

Who is responsible for wastewater monitoring? ______________________

Where are wastewater samples analyzed? ______________________

Part V - ECONOMIC DATA

A. Parent Organization Please indicate:

____	Public corporation	____	Proprietorship
____	Private "	____	Cooperative
____	Partnership	____	Other ______________

B. Plant Capacity - 1976

1. Length of shift ________ hours
   Number of Weeks at 0 shifts __________ (shutdown)
   at 1 shift __________
   at 2 shifts __________
   at 3 shifts __________
2. Plant capacity ______________________
3. Annual operating rate: 1975 ____% of plant capacity
   1976 ____% of plant capacity
4. Average Number of Employees (1976) ______________
5. Maximum Number of Employees (1976) ______________
6. Age (Year of initial construction) of major production facility ______________
   Average age of manufacturing equipment ______________

C. Water Pollution Costs: Direct Dischargers

		Before 1975	1975	1976	Projected 1977	Projected 1978 - 83
Annual Operating Costs	$	____	____	____	____	________
Capital Expenditures	$	____	____	____	____	________

WASTEWATER MONITORING DATA

Parameter	Units																															
Sample Collection Date																																
Waste Stream (Raw, Influent or Effluent)																																
Sample Type (grab, composite, etc.)																																
Approximate Corresponding Production (give units)																																
Average Flow Rate	mgd																															
BOD_5	mg/l																															
COD	mg/l																															
TSS	mg/l																															
Oil & Grease	mg/l																															
Phenol	mg/l																															
Total Chromium	ug/l																															
Sulfide	ug/l																															
Color	units																															
pH	units																															

Plant ____________________

Company ____________________

Company ____________________

Plant ____________________

Part V (Cont.)

D. Water Pollution Costs: Indirect Dischargers

Sewer use charges are based on:

____ Water usage

____ Wastewater volume

____ Other Basis (Please describe)

____ Wastewater concentration

BOD ______ COD ______

Suspended Solids ______

____

____

		Before 1975	1975	1976	1977	Projected 1978 - 83
Annual User Charges	$	____	____	____	____	________
Annual Capital Cost Recovery Charge	$	____	____	____	____	________
Pretreatment System Capital Cost	$	____	____	____	____	________
Annual Operating Cost	$	____	____	____	____	________

E. Other Regulatory Costs

Describe other regulatory controls (e.g. air, solid wastes, OSHA, etc.) that have resulted in significant costs impact.

____

____

Estimate combined investment and annual operating costs for other regulatory considerations over next 4 years.

Total investment cost per year $ ____________

Annual operating cost $ ____________

F. Energy Usage

Electric power usage for 1976 ________kwh Cost: ¢______/kwh

Fuel Oil usage for 1976 ________1000 gallons Cost: ¢______/gal

Gas (natural, propane, etc.) usage for 1976 ________1000 cu ft Cost: ¢______/cu ft

Approximate percentage of total energy usage attributable to water pollution controls ____%

Approximate percentage of total energy usage attributable to other regulatory controls ____%

Company ____ ____________

Plant ____________

Part VI - PRIORITY POLLUTANTS

Please complete the following Priority Pollutant listing. For each pollutant please check whether it is Known To Be Present, Suspected To Be Present, Suspected To Be Absent, or Known To Be Absent. Suitable responses should be based on the following descriptions:

Known To Be Present: The compound has been detected by reasonable analytical procedures in the discharge or by reference is known to be present in the raw waste load.

Suspected To Be Present: The compound is a raw material in the processes employed, a product, a by-product, catalyst, etc. Its presence in the raw waste load and discharge is a reasonable technical judgment.

Suspected To Be Absent: No known reason to predict that the compound is present in the discharge.

Known To Be Absent: The application of reasonable analytical procedures designed to detect the material have yielded negative results.

Priority Pollutant		Known Present	Suspected Present	Suspected Absent	Known Absent
1.	acenaphthene	____	____	____	____
2.	acrolein	____	____	____	____
3.	acrylonitrile	____	____	____	____
4.	benzene	____	____	____	____
5.	benzidine	____	____	____	____
6.	carbon tetrachloride (tetra chloromethane)	____	____	____	____
7.	chlorobenezene	____	____	____	____
8.	1,2,4-trichlorobenzene	____	____	____	____
9.	hexachlorobenzene	____	____	____	____
10.	1,2-dichloroethane	____	____	____	____
11.	1,1,1-trichlorethane	____	____	____	____
12.	hexachloroethane	____	____	____	____
13.	1,1-dichloroethane	____	____	____	____
14.	1,1,2-trichloroethane	____	____	____	____
15.	1,1,2,3-tetrachloroethane	____	____	____	____
16.	chloroethane	____	____	____	____
17.	bis(chloromethyl) ether	____	____	____	____
18.	bis(2-chloroethyl) ether	____	____	____	____
19.	2-chloroethyl vinyl ether (mixed)	____	____	____	____
20.	2-chloronaphthalene	____	____	____	____
21.	2,4,6-trichlorophenol	____	____	____	____
22.	parachlorometa cresol	____	____	____	____
23.	chloroform (trichloromethane)	____	____	____	____
24.	2-chlorophenol	____	____	____	____

Company ______ ______________________

Plant ____________________________

Part VI (Cont.)

Priority Pollutant	Known Present	Suspected Present	Suspected Absent	Known Absent
25. 1,2-dichlorobenzene				
26. 1,3-dichlorobenzene				
27. 1,4-dichlorobenzene				
28. 3,3-dichlorobenzidine				
29. 1,1-dichloroethylene				
30. 1,2-trans-dichloroethylene				
31. 2,4-dichlorophenol				
32. 1,2-dichloropropane				
33. 1,3-dichloropropylene (1,3-dichloropropene)				
34. 2,4-dimethylphenol				
35. 2,4-dinitrotoluene				
36. 2,6-dinitrotoluene				
37. 1,2-diphenylhydrazine				
38. ethylbenzene				
39. fluoranthene				
40. 4-chlorophenyl phenyl ether				
41. 4-bromophenyl phenyl ether				
42. bis(2-chloroisopropyl) ether				
43. bis(2-chloroethoxy) methane				
44. methylene chloride (dichloromethane)				
45. methyl chloride (chloromethane)				
46. methyl bromide (bromomethane)				
47. bromoform (tribromomethane)				
48. dichlorobromomethane				
49. trichlorofluoromethane				
50. dichlorodifluoromethane				
51. chlorodibromomethane				
52. hexachlorobutadiene				
53. hexachlorocyclopentadiene				
54. isophorone				
55. napthalene				
56. nitrobenzene				

Company ______________________

Plant ______________________

Part VI (Cont.)

Priority Pollutant	Known Present	Suspected Present	Suspected Absent	Known Absent
57. 2-nitrophenol	___	___	___	___
58. 4-nitrophenol	___	___	___	___
59. 2,4-dinitrophenol	___	___	___	___
60. 4,6-dinitro-o-cresol	___	___	___	___
61. N-nitrosodimethylamine	___	___	___	___
62. N-nitrosodiphenylamine	___	___	___	___
63. N-nitrosodi-n-propylamine	___	___	___	___
64. pentachlorophenol	___	___	___	___
65. phenol	___	___	___	___
66. bis(2-ethylhexyl) phthalate	___	___	___	___
67. butyl benzyl phthalate	___	___	___	___
68. di-n-butyl phthalate	___	___	___	___
69. diethyl phthalate	___	___	___	___
70. dimethyl phthalate	___	___	___	___
71. 1,2-benzathracene	___	___	___	___
72. benzo (a)pyrene (3,4-benzo pyrene)	___	___	___	___
73. 3,4-benzofluoranthene	___	___	___	___
74. 11,12-benzofluoranthene	___	___	___	___
75. chrysene	___	___	___	___
76. acenaphthylene	___	___	___	___
77. anthracene	___	___	___	___
78. 1,12-benzoperylene	___	___	___	___
79. fluorene	___	___	___	___
80. phenanthrene	___	___	___	___
81. 1,2:5,6-dibenzanthracene	___	___	___	___
82. indeno(1,2,3-C,D) pyrene	___	___	___	___
83. pyrene	___	___	___	___
84. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)	___	___	___	___
85. tetrachloroethylene	___	___	___	___
86. toluene	___	___	___	___
87. trichloroethylene	___	___	___	___
88. vinyl chlorine (chloroethylene)	___	___	___	___
Pesticides and Metabolites				
89. aldrin	___	___	___	___
90. dieldrin	___	___	___	___
91. chlordane (technical mixture and metabolites)	___	___	___	___

Company ______________________

Plant ______________________

Part VI (Cont.)

Priority Pollutant	Known Present	Suspected Present	Suspected Absent	Known Absent
92. 4,4'-DDT	____	____	____	____
93. 4,4'-DDE (p,p'-DDX)	____	____	____	____
94. 4,4'-DDD (p,p'-TDE)	____	____	____	____
95. a-endosulfan	____	____	____	____
96. B-endosulfan	____	____	____	____
97. endosulfan sulfate	____	____	____	____
98. endrin	____	____	____	____
99. endrin aldehyde	____	____	____	____
100. heptachlor	____	____	____	____
101. heptachlor epoxide	____	____	____	____
102. a-BHC	____	____	____	____
103. B-BHC	____	____	____	____
104. γ-BHC (lindane)	____	____	____	____
105. δ-BHC	____	____	____	____
106. PCB-1242 (Arochlor 1242)	____	____	____	____
107. PCB-1254 (Arochlor 1254)	____	____	____	____
108. Toxaphene	____	____	____	____
Metals				
109. Antimony (Total)	____	____	____	____
110. Arsenic (Total)	____	____	____	____
111. Asbestos (Fibrow)	____	____	____	____
112. Beryllium (Total)	____	____	____	____
113. Cadmium (Total)	____	____	____	____
114. Chromium (Total)	____	____	____	____
115. Copper (Total)	____	____	____	____
116. Cyanide (Total)	____	____	____	____
117. Lead (Total)	____	____	____	____
118. Mercury (Total)	____	____	____	____
119. Nickel (Total)	____	____	____	____
120. Selenium (Total)	____	____	____	____
121. Silver (Total)	____	____	____	____
122. Thallium (Total)	____	____	____	____
123. Zinc (Total)	____	____	____	____

Company ______________________

Plant ______________________

Part VI (Cont.)

For those Priority Pollutants which are known to be present, please indicate to the best of your knowledge the prime source of the material.

Specific Pollutant	Source (Raw Material/Process Line)

QUESTIONNAIRE COMPILATION

Please provide the following information regarding completion of questionnaire.

Compiler ______________________ Title ______________________

Office Location ______________________ Telephone ______________________

Date Completed ______________________

If you have questions, please contact Dr. James Buzzell or Larry Oliver at (314) 436-7600, Ext. 347 or 243.

FIGURE A-3

EPA INDUSTRY SURVEY
TEXTILE PLANTS
BAT-NSPS-PRETREATMENT

Please complete as many of the questionnaire items as possible and return to:

Larry J. Oliver
Sverdrup & Parcel and Associates, Inc.
800 N. 12th Blvd.
St. Louis, MO 63101
Tel: (314) 436-7600 Ext. 243 or 347

Company ______________________ Plant ______________________

Plant Location ____

PART I - MANUFACTURING INFORMATION

A. Plant Classification (Please indicate average 1976 production per day for the appropriate subcategory(ies).)

Subcategory	lb/day	Subcategory	lb/day
1. Wool Scouring	______	4. Woven Fabric Finishing	______
2. Wool Finishing	______	5. Knit Fabric Finishing	______
3. Dry Processing		6. Carpet Mill	______
Woven Greige Goods	______	7. Stock & Yarn	______
Knit Greige Goods	______	8. Nonwovens	______
Other	______	9. Miscellaneous (describe on reverse side)	______

B. Please indicate principal manufactured product(s) (e.g. knit fabric, woven fabric, hosiery, carpet, thread, etc.)

____

C. Raw Materials (Please indicate average pounds fiber use per day.)

Fiber Content	lb/day	Fiber Blends (e.g. 65% cotton/35% polyester)	lb/day
Wool	______	______________	______
Cotton	______	______________	______
Polyester	______	______________	______
Rayon	______	______________	______
Nylon	______	Other Fibers (identify)	
Acetate	______	______________	______
Acrylic	______	______________	______
Modacrylic	______	______________	______

D. Production Process Information (Please indicate approximate percent of production through the following processes.)

Percent	Process
______	Slashing: ____% Starch; ____% PVA; ____% CMC; ____% other
______	Weaving: Type of machinery ______________________
______	Knitting: Type of machinery ______________________
______	Other (Desizing, Scouring, Bleaching, Mercerizing, Dyeing, Printing, etc.) Please describe: ______________________

PART II - WASTEWATER INFORMATION

A. Approximately how many gallons of wastewater are discharged, on the average, per day. ______________ gpd.

B. Please indicate the approximate percentage of the total flow from each source:

- ______ % Process-related wastewater (slasher cleanup, contact cooling water, equipment washdown, other sources)
- ______ % Boiler blowdown
- ______ % Non-contact cooling water
- ______ % Sanitary sewage
- ______ % Cafeteria
- ______ % Air pollution control equipment
- ______ % Other (describe): ______________________

C. Process-related wastewater is discharged: (please check or indicate.)

- ______ Continuously
- ______ Times per day
- ______ Times per week
- ______ Intermittently (describe): ______________________
- ______ Other (describe): ______________________

D. Is wastewater treated? (e.g., screening, holding tank, aeration, etc.)

____Yes ____No (If yes, please attach a simple block diagram of the treatment system.)

E. Please indicate method used to dispose of process-related wastewaters.

____ Direct Discharge - Discharge of treated or untreated process-related wastewaters directly to a receiving body of water.

____ Indirect Discharge - Discharge of partially treated or untreated process-related wastewaters directly to a Publicly Owned Treatment Works (POTW) via municipal sewer system.

____ Other Discharge such as septic tank, evaporation lagoon, irrigation system, etc. Please explain briefly below.

____

F. Are monitoring data available for process-related wastewater discharge?

____ No - No monitoring is done.

____ Yes - Monitored by municipal water pollution control agency

____ Yes - Monitored and reported under NPDES permit

____ Yes - Other reason

If yes, please attach copies of reports for 1976 and 1977 monitoring.

G. In-Plant Control Information: Has your plant instituted in-plant controls to reduce water pollution? ___Yes ___No (Please check those applicable.)

________ Water reuse

________ Water recycle

________ Chemical substitution

________ Material reclamation

________ Other: ____________________

PART III - PLANT INFORMATION

A. Plant Capacity - 1976

1. 1976 production was approximately ______% of plant's full production capacity.

2. 1976 operating experience:

Length of shifts - ______ hours

Average number of shifts - _______ per week

Plant shut down - _______ weeks

3. Average number of employees:

1st shift __________

2nd shift __________

3rd shift __________

4. Plant Age:

Approximate age of major production facilities - ______ years

Average age of manufacturing equipment - ______ years

Date of latest major remodeling or expansion - ______________

B. Value of Production - (Please indicate the approximate value of principal manufactured products or principal production services for 1976.)

____Less than $\frac{1}{2}$ million $/year	____5 to 10 million $/year
____$\frac{1}{2}$ to 1 million $/year	____10 to 25 million $/year
____1 to 5 million $/year	____Greater than 25 million $/year

C. Energy Usage - 1976

Average electric power usage - ________kwh/month Cost - $________/month

Average fuel oil usage - ________1000 gal/month Cost - $________/month

Average gas usage - ________1000 cu ft/month Cost - $________/month

PART IV - PRIORITY POLLUTANTS

A. Please circle the reference number for each pollutant or pollutant class listed below that you know or suspect are present in your raw wastewater discharge.

1. acenaphthene
2. acrolein
3. acrylonitrile
4. benzene
5. benzidine
6. carbon tetrachloride (tetrachloromethane)
7. chlorinated benezenes
8. chlorinated ethanes
9. chloroalkyl ethers
10. chlorinated naphthalene
11. chlorinated phenols
12. chloroform (trichloromethane)
13. 2-chlorophenol
14. dichlorobenzenes
15. dichlorobenzidine
16. dichloroethylenes
17. 2,4-dichlorophenol
18. dichloropropane and dichloropropene
19. 2,4-dimethylphenol
20. dinitrotoluene
21. 1,2-diphenylhydrazine
22. ethylbenzene
23. fluroanthene
24. haloethers
25. halomethane
26. hexachlorobutadiene
27. hexachlorocyclopentadiene
28. isophorone
29. naphthalene
30. nitrobenzene
31. nitrophenols
32. nitosamines
33. pentacholorphenol
34. phenol
35. phthalate esters
36. polynuclear aromatic hydrocarbons
37. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)
38. tetrachloroethylene
39. toluene
40. trichloroethylene
41. vinyl chloride (chloroethylene)

Pesticides and Metabolites

42. aldrin/dieldrin
43. chlordane
44. DDT
45. endosulfan

46. endrin
47. heptachlor
48. hexachlorocyclohexane
49. polychlorinated biphenyls (PCB's)
50. toxaphene

Metals

51. antimony (total)
52. arsenic (total)
53. asbestos (Fibrow)
54. beryllium (total)
55. cadium (total)

56. chromium (total)
57. copper (total)
58. cyanide (total)
59. lead (total)
60. mercury (total)

61. nickel (total)
62. selenium (total)
63. silver (total)
64. thallium (total)
65. zinc (total)

B. For those Priority Pollutants that are known or suspected present, please indicate to the best of your knowledge the prime source of the material.

Specific Pollutant	Source (Raw Material/Process Line)
______________	______________
______________	______________
______________	______________
______________	______________
______________	______________

QUESTIONNAIRE COMPILATION

Please provide the following information regarding completion of questionnaire.

Compiler ______________________ Title ______________

Office Location ______________________ Telephone ______________

Date Completed ______________________

If you have questions, please contact Dr. James Buzzell or Larry Oliver at (314) 436-7600, Ext. 347 or 243.

Additional comments

A-1

APPENDIX B

WASTEWATER CHARACTERIZATION DATA

TABLE B-1 - RAW WASTE CHARACTERISTICS - SUMMARY OF HISTORICAL DATA

TABLE B-2 - BPT EFFLUENT CHARACTERISTICS - SUMMARY OF HISTORICAL DATA

TABLE B-1
RAW WASTE CHARACTERISTICS - SUMMARY OF HISTORICAL DATA

Subcategory	Wastewater Discharge, 10^3 cu m/day Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	0.038	2.84	0.503	0.193	11
2. Wool Finishing	0.189	15.8	3.02	1.89	15
3. Low Water Use Processing	0.023	1.05	0.30	0.23	13
4. Woven Fabric Finishing					
a. Simple Processing	0.057	20.8	1.97	0.636	48
b. Complex Processing	0.042	28.9	4.28	1.53	39
c. Complex Processing Plus Desizing	0.034	20.8	1.89	0.636	51
5. Knit Fabric Finishing					
a. Simple Processing	0.011	10.6	2.13	1.51	71
b. Complex Processing	0.114	13.2	2.41	2.00	35
c. Hosiery Products	0.004	1.54	0.227	0.178	57
6. Carpet Finishing	0.076	6.92	1.91	1.59	37
7. Stock & Yarn Finishing	0.045	9.65	1.59	0.961	116
8. Nonwoven Manufacturing	0.011	1.51	0.620	0.564	11
9. Felted Fabric Processing	0.053	1.89	0.685	0.378	11

TABLE B-1 (Cont.)

Subcategory		BOD_5, mg/l			
	Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	313	6680	2950	2270	9
2. Wool Finishing	66	750	233	166	10
3. Low Water Use Processing	37	2546	466	293	13
4. Woven Fabric Finishing					
a. Simple Processing	19	2050	392	269	32
b. Complex Processing	83	2160	462	350	23
c. Complex Processing Plus Desizing	125	2600	519	416	36
5. Knit Fabric Finishing					
a. Simple Processing	60	1860	289	209	35
b. Complex Processing	123	921	304	266	19
c. Hosiery Products	38	792	358	323	39
6. Carpet Finishing	188	565	415	439	10
7. Stock & Yarn Finishing	43	1630	279	185	62
8. Nonwoven Manufacturing	55	376	209	203	4
9. Felted Fabric Processing	64	633	262	176	4

Table B-1 (Cont.)

Subcategory	BOD_5, kg/kkg of Production Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	3.80	207.09	54.15	41.79	9
2. Wool Finishing	22.36	139.51	69.54	59.77	10
3. Low Water Use Processing	0.22	22.36	6.57	2.32	13
4. Woven Fabric Finishing					
a. Simple Processing	3.77	215.35	36.75	22.64	32
b. Complex Processing	3.59	96.05	36.99	32.74	23
c. Complex Processing Plus Desizing	5.90	188.51	53.57	45.12	36
5. Knit Fabric Finishing					
a. Simple Processing	4.44	85.06	31.49	27.74	35
b. Complex Processing	8.04	137.69	32.51	22.10	19
c. Hosiery Products	1.59	138.33	34.19	26.42	39
6. Carpet Finishing	13.73	40.78	24.86	25.57	10
7. Stock & Yarn Finishing	0.75	113.00	28.18	20.74	62
8. Nonwoven Manufacturing	15.43	309.97	116.46	70.23	4
9. Felted Fabric Processing	3.27	16.14	8.19	6.69	4

TABLE B-1 (Cont.)

Subcategory	COD, mg/l Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	1140	17800	8260	7030	4
2. Wool Finishing	280	2000	818	592	7
3. Low Water Use Processing	115	2955	873	692	8
4. Woven Fabric Finishing					
a. Simple Processing	203	5020	1170	901	28
b. Complex Processing	244	5140	1470	1060	12
c. Complex Processing Plus Desizing	372	2780	1350	1240	29
5. Knit Fabric Finishing					
a. Simple Processing	342	19400	1630	873	29
b. Complex Processing	545	3150	1160	791	11
c. Hosiery Products	450	4980	1500	1370	27
6. Carpet Finishing	281	2120	1200	1188	14
7. Stock & Yarn Finishing	136	4760	962	684	46
8. Nonwoven Manufacturing	230	2090	857	553	4
9. Felted Fabric Processing	205	3940	2170	2360	3

TABLE B-1 (Cont.)

Subcategory	COD, kg/kkg of Production				
	Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	20.10	749.73	256.92	128.93	4
2. Wool Finishing	97.35	445.11	222.43	204.81	7
3. Low Water Use Processing	2.74	25.96	14.20	14.50	8
4. Woven Fabric Finishing					
a. Simple Processing	12.70	436.82	108.00	92.40	28
b. Complex Processing	10.18	388.01	128.28	110.62	12
c. Complex Processing Plus Desizing	48.04	798.32	157.27	122.63	29
5. Knit Fabric Finishing					
a. Simple Processing	17.90	378.79	121.51	81.11	29
b. Complex Processing	49.43	503.01	139.75	115.45	11
c. Hosiery Products	26.05	625.76	126.70	89.38	27
6. Carpet Finishing	21.88	134.89	73.82	82.32	14
7. Stock & Yarn Finishing	2.46	380.40	90.12	62.71	46
8. Nonwoven Manufacturing	63.97	379.96	703.97	185.98	4
9. Felted Fabric Processing	10.38	99.44	49.40	38.39	3

TABLE B-1 (Cont.)

Subcategory		TSS, mg/l Min.	Max.	Avg.	Med.	No.
1.	Wool Scouring	120	13200	4210	3310	8
2.	Wool Finishing	17	245	89	62	10
3.	Low Water Use Processing	10	532	181	185	12
4.	Woven Fabric Finishing					
	a. Simple Processing	16	2440	266	62	26
	b. Complex Processing	40	866	177	107	18
	c. Complex Processing Plus Desizing	1	1260	214	154	28
5.	Knit Fabric Finishing					
	a. Simple Processing	21	2160	147	53	32
	b. Complex Processing	18	742	137	60	19
	c. Hosiery Products	9	182	83	82	29
6.	Carpet Finishing	37	208	81	67	12
7.	Stock & Yarn Finishing	2	4200	142	38	59
8.	Nonwoven Manufacturing	68	285	147	117	4
9.	Felted Fabric Processing	59	179	98	78	4

TABLE B-1 (Cont.)

Subcategory	Min.	Max.	Avg.	Med.	No.
	TSS, kg/kkg of Production				
1. Wool Scouring	1.91	235.55	64.92	43.10	8
2. Wool Finishing	9.53	97.10	27.42	17.20	10
3. Low Water Use Processing	0.33	4.03	1.73	1.58	12
4. Woven Fabric Finishing					
a. Simple Processing	0.81	222.11	27.23	7.96	26
b. Complex Processing	1.95	61.68	14.95	9.63	18
c. Complex Processing Plus Desizing	0.20	83.50	23.17	14.76	28
5. Knit Fabric Finishing					
a. Simple Processing	2.91	41.50	9.55	6.34	32
b. Complex Processing	1.32	110.04	17.97	6.95	19
c. Hosiery Products	0.32	23.59	7.84	6.73	29
6. Carpet Finishing	1.55	9.27	4.93	4.66	12
7. Stock & Yarn Finishing	0.09	478.45	14.42	4.57	59
8. Nonwoven Manufacturing	15.94	119.72	65.97	64.11	4
9. Felted Fabric Processing	0.24	14.81	4.85	2.19	4

TABLE B-1 (Cont.)

Subcategory	Oil & Grease, mg/l Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	80	5000	1560	580	7
2. Wool Finishing	-	-	70	-	1
3. Low Water Use Processing	-	-	-	-	0
4. Woven Fabric Finishing					
a. Simple Processing	6	1440	271	69	11
b. Complex Processing	34	158	69	46	6
c. Complex Processing Plus Desizing	5	100	57	68	5
5. Knit Fabric Finishing					
a. Simple Processing	14	455	123	83	9
b. Complex Processing	6	113	58	52	6
c. Hosiery Products	15	275	113	99	13
6. Carpet Finishing	3	93	30	18	5
7. Stock & Yarn Finishing	1	180	36	21	18
8. Nonwoven Manufacturing	8	156	64	28	3
9. Felted Fabric Processing	-	-	81	-	1

TABLE B-1 (Cont.)

Subcategory	Oil & Grease, kg/kkg of Production Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	1.27	62.44	20.83	10.26	7
2. Wool Finishing	-	-	7.78	-	1
3. Low Water Use Processing	-	-	-	-	0
4. Woven Fabric Finishing					
a. Simple Processing	0.65	151.25	25.31	9.08	11
b. Complex Processing	2.24	14.24	5.52	3.84	6
c. Complex Processing Plus Desizing	0.36	14.93	5.22	4.08	5
5. Knit Fabric Finishing					
a. Simple Processing	0.53	46.43	12.92	3.99	9
b. Complex Processing	0.45	17.85	5.51	3.54	6
c. Hosiery Products	1.44	27.74	9.15	6.63	13
6. Carpet Finishing	0.23	9.37	2.61	1.08	5
7. Stock & Yarn Finishing	0.05	21.52	3.45	1.64	18
8. Nonwoven Manufacturing	2.36	126.40	46.63	11.15	3
9. Felted Fabric Processing	-	-	3.41	-	1

TABLE B-1 (Cont.)

Subcategory	Phenol, ug/l Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	-	-	-	-	0
2. Wool Finishing	50	155	102	102	2
3. Low Water Use Processing	-	-	91	-	1
4. Woven Fabric Finishing					
a. Simple Processing	10	600	178	49	10
b. Complex Processing	10	600	179	54	6
c. Complex Processing Plus Desizing	14	1220	426	146	5
5. Knit Fabric Finishing					
a. Simple Processing	1	1680	351	110	9
b. Complex Processing	72	230	128	100	5
c. Hosiery Products	26	583	118	62	10
6. Carpet Finishing	1	1140	301	130	7
7. Stock & Yarn Finishing	3	621	223	172	12
8. Nonwoven Manufacturing	70	1100	580	575	3
9. Felted Fabric Processing	-	-	21	-	1

TABLE B-1 (Cont.)

Subcategory	Phenol, g/kkg of Production				
	Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	-	-	-	-	0
2. Wool Finishing	11.37	75.42	43.39	43.39	2
3. Low Water Use Processing	-	-	2.34	-	1
4. Woven Fabric Finishing					
a. Simple Processing	1.76	51.21	14.29	8.15	10
b. Complex Processing	0.91	25.03	10.33	7.69	4
c. Complex Processing Plus Desizing	0.93	149.32	52.69	13.10	6
5. Knit Fabric Finishing					
a. Simple Processing	0.10	397.35	64.10	8.71	9
b. Complex Processing	3.42	36.73	16.65	12.01	5
c. Hosiery Products	1.84	151.59	20.88	4.23	10
6. Carpet Finishing	0.04	58.91	20.44	11.34	7
7. Stock & Yarn Finishing	0.53	83.44	22.92	15.03	12
8. Nonwoven Manufacturing	16.41	497.56	587.11	247.35	3
9. Felted Fabric Processing	-	-	0.19	-	1

TABLE B-1 (Cont.)

Subcategory	Total Chromium, ug/l				
	Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	-	-	-	-	0
2. Wool Finishing	100	343	221	221	2
3. Low Water Use Processing	15	97	56	56	2
4. Woven Fabric Finishing					
a. Simple Processing	1	530	102	38	16
b. Complex Processing	19	1180	245	110	7
c. Complex Processing Plus Desizing	14	12500	2050	100	11
5. Knit Fabric Finishing					
a. Simple Processing	13	600	119	78	13
b. Complex Processing	10	180	72	80	8
c. Hosiery Products	10	1200	213	80	17
6. Carpet Finishing	4	300	96	30	7
7. Stock & Yarn Finishing	4	1600	344	100	25
8. Nonwoven Manufacturing	50	500	275	275	2
9. Felted Fabric Processing	10	370	143	50	3

TABLE B-1 (Cont.)

Subcategory	Min.	Max.	Avg.	Med.	No.
	Total Chromium, g/kkg of Production				
1. Wool Scouring	-	-	-	-	0
2. Wool Finishing	65.77	162.89	114.33	114.33	2
3. Low Water Use Processing	1.47	3.42	2.44	2.44	2
4. Woven Fabric Finishing					
a. Simple Processing	0.07	43.76	8.19	4.30	16
b. Complex Processing	2.37	49.23	15.32	2.62	7
c. Complex Processing Plus Desizing	0.57	1521.01	239.58	20.86	11
5. Knit Fabric Finishing					
a. Simple Processing	0.64	85.25	17.29	7.82	13
b. Complex Processing	1.35	35.04	11.64	4.71	8
c. Hosiery Products	0.35	265.63	29.03	6.38	17
6. Carpet Finishing	0.22	11.92	5.23	3.44	7
7. Stock & Yarn Finishing	0.83	362.86	51.60	11.99	25
8. Nonwoven Manufacturing	11.72	139.07	75.39	75.39	2
9. Felted Fabric Processing	0.43	15.59	5.50	0.50	3

TABLE B-1 (Cont.)

Subcategory	Sulfide, ug/l Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	-	-	-	-	0
2. Wool Finishing	-	-	-	-	0
3. Low Water Use Processing	-	-	180	-	1
4. Woven Fabric Finishing					
a. Simple Processing	25	580	155	72	6
b. Complex Processing	100	120	106	100	3
c. Complex Processing Plus Desizing	100	4400	2260	2260	2
5. Knit Fabric Finishing					
a. Simple Processing	20	7100	2390	55	3
b. Complex Processing	50	1470	457	155	4
c. Hosiery Products	10	8000	2280	562	4
6. Carpet Finishing	10	450	202	175	4
7. Stock & Yarn Finishing	1	4437	869	200	9
8. Nonwoven Manufacturing	-	-	500	-	1
9. Felted Fabric Processing	-	-	10	-	1

TABLE B-1 (Cont.)

Subcategory	Min.	Max.	Avg.	Med.	No.
	Sulfide, g/kkg of Production				
1. Wool Scouring	-	-	-	-	0
2. Wool Finishing	-	-	-	-	0
3. Low Water Use Processing	-	-	3.79	-	1
4. Woven Fabric Finishing					
a. Simple Processing	0.58	128.21	28.24	7.59	6
b. Complex Processing	7.84	19.88	13.41	12.51	3
c. Complex Processing Plus Desizing	15.73	293.72	154.72	154.72	2
5. Knit Fabric Finishing					
a. Simple Processing	3.12	769.42	261.86	13.04	3
b. Complex Processing	8.34	110.39	36.70	14.04	4
c. Hosiery Products	1.98	400.53	151.59	101.94	4
6. Carpet Finishing	0.77	22.00	10.40	9.42	4
7. Stock & Yarn Finishing	0.55	169.30	48.43	27.81	9
8. Nonwoven Manufacturing	-	-	117.27	-	1
9. Felted Fabric Processing	-	-	0.50	-	1

TABLE B-1 (Cont.)

Subcategory	Color, APHA Units Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	-	-	-	-	0
2. Wool Finishing	-	-	1500	-	1
3. Low Water Use Processing	-	-	-	-	0
4. Woven Fabric Finishing					
a. Simple Processing	20	10000	2510	800	9
b. Complex Processing	317	700	508	508	2
c. Complex Processing Plus Desizing	-	-	-	-	0
5. Knit Fabric Finishing					
a. Simple Processing	170	1460	547	400	9
b. Complex Processing	37	937	629	750	7
c. Hosiery Products	40	1060	504	453	8
6. Carpet Finishing	65	1900	734	486	4
7. Stock & Yarn Finishing	57	3000	922	566	11
8. Nonwoven Manufacturing	-	-	300	-	1
9. Felted Fabric Processing	-	-	28	-	1

TABLE B-2
BPT EFFLUENT CHARACTERISTICS - SUMMARY OF HISTORICAL DATA

Subcategory	BOD_5, mg/l				
	Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	60	125	92	92	2
2. Wool Finishing	24	76	50	50	2
3. Low Water Use Processing	7	100	30	24	17
4. Woven Fabric Finishing					
a. Simple Processing	4	124	33	15	7
b. Complex Processing	3	101	35	24	7
c. Complex Processing Plus Desizing	3	151	36	24	17
5. Knit Fabric Finishing					
a. Simple Processing	4	143	32	13	13
b. Complex Processing	5	45	24	21	5
c. Hosiery Products	44	98	71	71	2
6. Carpet Finishing	27	54	36	34	6
7. Stock & Yarn Finishing	3	29	13	11	10
8. Nonwoven Manufacturing	-	-	-	-	0
9. Felted Fabric Processing	-	-	-	-	0

TABLE B-2 (Cont.)

Subcategory		BOD5, kg/kkg of Production				
		Min.	Max.	Avg.	Med.	No.
1.	Wool Scouring	0.40	7.66	4.03	4.03	2
2.	Wool Finishing	12.22	37.95	25.08	25.08	2
3.	Low Water Use Processing	0.03	4.88	0.86	0.14	16
4.	Woven Fabric Finishing					
	a. Simple Processing	0.79	18.77	4.78	2.59	7
	b. Complex Processing	0.54	15.40	4.94	4.05	7
	c. Complex Processing Plus Desizing	0.51	13.65	3.12	2.14	17
5.	Knit Fabric Finishing					
	a. Simple Processing	0.30	9.97	2.84	1.62	13
	b. Complex Processing	0.25	8.31	3.09	3.17	5
	c. Hosiery Products	1.82	6.18	4.00	4.00	2
6.	Carpet Finishing	1.01	4.77	2.02	1.59	6
7.	Stock & Yarn Finishing	0.23	3.31	1.17	0.82	10
8.	Nonwoven Manufacturing	-	-	-	-	0
9.	Felted Fabric Processing	-	-	-	-	0

TABLE B-2 (Cont.)

Subcategory	Min.	Max.	Avg.	Med.	No.
	COD, mg/l				
1. Wool Scouring	1440	2600	2020	2020	2
2. Wool Finishing	-	-	534	-	1
3. Low Water Use Processing	51	602	280	223	9
4. Woven Fabric Finishing					
a. Simple Processing	141	409	262	242	6
b. Complex Processing	86	714	311	246	6
c. Complex Processing Plus Desizing	155	912	360	252	13
5. Knit Fabric Finishing					
a. Simple Processing	154	1750	439	274	11
b. Complex Processing	124	597	322	277	5
c. Hosiery Products	-	-	571	-	1
6. Carpet Finishing	227	546	328	286	5
7. Stock & Yarn Finishing	96	268	154	140	10
8. Nonwoven Manufacturing	-	-	-	-	0
9. Felted Fabric Processing	-	-	-	-	0

TABLE B-2 (Cont.)

Subcategory	Min.	Max.	Avg.	Med.	No.
	COD, kg/kkg of Production				
1. Wool Scouring	8.93	155.11	82.02	82.02	2
2. Wool Finishing	-	-	273.09	-	1
3. Low Water Use Processing	0.56	20.89	5.72	2.68	9
4. Woven Fabric Finishing					
a. Simple Processing	17.67	71.71	38.43	33.62	6
b. Complex Processing	17.87	109.98	47.59	39.03	6
c. Complex Processing Plus Desizing	4.69	82.03	34.49	29.40	13
5. Knit Fabric Finishing					
a. Simple Processing	8.68	122.10	48.67	28.58	11
b. Complex Processing	5.84	68.26	33.76	40.45	5
c. Hosiery Products	-	-	23.73	-	1
6. Carpet Finishing	8.72	33.71	17.61	15.31	5
7. Stock & Yarn Finishing	4.91	42.94	15.63	11.38	10
8. Nonwoven Manufacturing	-	-	-	-	0
9. Felted Fabric Processing	-	-	-	-	0

TABLE B-2 (Cont.)

Subcategory	TSS, mg/l Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	166	1230	698	698	2
2. Wool Finishing	49	141	95	95	2
3. Low Water Use Processing	8	159	35	28	16
4. Woven Fabric Finishing					
a. Simple Processing	18	56	39	38	7
b. Complex Processing	18	95	45	48	7
c. Complex Processing Plus Desizing	8	176	65	49	17
5. Knit Fabric Finishing					
a. Simple Processing	11	187	57	34	13
b. Complex Processing	18	116	62	55	5
c. Hosiery Products	-	-	129	-	1
6. Carpet Finishing	33	113	69	63	6
7. Stock & Yarn Finishing	9	71	30	25	10
8. Nonwoven Manufacturing	-	-	-	-	0
9. Felted Fabric Processing	-	-	-	-	0

TABLE B-2 (Cont.)

Subcategory			TSS, kg/kkg of Production			
		Min.	Max.	Avg.	Med.	No.
1.	Wool Scouring	1.00	74.69	37.84	37.84	2
2.	Wool Finishing	24.48	68.22	46.35	46.35	2
3.	Low Water Use Processing	0.03	3.61	0.63	0.22	15
4.	Woven Fabric Finishing					
	a. Simple Processing	2.27	11.26	6.31	4.76	7
	b. Complex Processing	3.20	10.11	6.65	7.55	7
	c. Complex Processing Plus Desizing	0.65	19.38	6.00	4.56	17
5.	Knit Fabric Finishing					
	a. Simple Processing	1.56	12.83	5.81	3.53	13
	b. Complex Processing	1.00	17.17	7.39	5.89	5
	c. Hosiery Products	-	-	5.35	-	1
6.	Carpet Finishing	1.58	10.93	4.03	3.11	6
7.	Stock & Yarn Finishing	0.34	7.24	2.95	2.09	10
8.	Nonwoven Manufacturing	-	-	-	-	0
9.	Felted Fabric Processing	-	-	-	-	0

TABLE B-2 (Cont.)

Subcategory	Oil & Grease, mg/l Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	-	-	187	-	1
2. Wool Finishing	-	-	-	-	0
3. Low Water Use Processing	-	-	-	-	0
4. Woven Fabric Finishing					
a. Simple Processing	-	-	24	-	1
b. Complex Processing	-	-	-	-	0
c. Complex Processing Plus Desizing	5	14	9	9	5
5. Knit Fabric Finishing					
a. Simple Processing	8	110	46	14	5
b. Complex Processing	-	-	32	-	1
c. Hosiery Products	-	-	-	-	0
6. Carpet Finishing	-	-	6	-	1
7. Stock & Yarn Finishing	-	-	-	-	0
8. Nonwoven Manufacturing	-	-	-	-	0
9. Felted Fabric Processing	-	-	-	-	0

TABLE B-2 (Cont.)

Subcategory	Oil & Grease, kg/kkg of Production Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	-	-	11.22	-	1
2. Wool Finishing	-	-	-	-	0
3. Low Water Use Processing	-	-	-	-	0
4. Woven Fabric Finishing					
a. Simple Processing	-	-	5.18	-	1
b. Complex Processing	-	-	-	-	0
c. Complex Processing Plus Desizing	0.42	3.30	1.29	1.05	5
5. Knit Fabric Finishing					
a. Simple Processing	0.75	12.35	4.47	1.07	5
b. Complex Processing	-	-	5.93	-	1
c. Hosiery Products	-	-	-	-	0
6. Carpet Finishing	-	-	0.71	-	1
7. Stock & Yarn Finishing	-	-	-	-	0
8. Nonwoven Manufacturing	-	-	-	-	0
9. Felted Fabric Processing	-	-	-	-	0

TABLE B-2 (Cont.)

Subcategory	Phenol, ug/l Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	-	-	101	-	1
2. Wool Finishing	-	-	81	-	1
3. Low Water Use Processing	29	100	64	64	2
4. Woven Fabric Finishing					
a. Simple Processing	10	87	34	20	7
b. Complex Processing	25	250	129	112	3
c. Complex Processing Plus Desizing	2	347	85	34	8
5. Knit Fabric Finishing					
a. Simple Processing	8	323	93	56	6
b. Complex Processing	30	100	65	65	2
c. Hosiery Products	-	-	34	-	1
6. Carpet Finishing	80	370	155	100	5
7. Stock & Yarn Finishing	40	186	82	56	5
8. Nonwoven Manufacturing	-	-	-	-	0
9. Felted Fabric Processing	-	-	-	-	0

TABLE B-2 (Cont.)

Subcategory	Phenol, g/kkg of Production				
	Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	-	-	6.16	-	1
2. Wool Finishing	-	-	39.62	-	1
3. Low Water Use Processing	0.54	0.59	0.56	0.56	2
4. Woven Fabric Finishing					
a. Simple Processing	1.57	14.15	5.63	2.78	7
b. Complex Processing	3.42	73.80	31.52	17.35	3
c. Complex Processing Plus Desizing	0.24	72.79	13.63	3.01	8
5. Knit Fabric Finishing					
a. Simple Processing	0.61	21.08	8.47	7.80	6
b. Complex Processing	2.26	19.10	10.68	10.68	2
c. Hosiery Products	-	-	1.44	-	1
6. Carpet Finishing	2.46	49.06	13.68	4.76	5
7. Stock & Yarn Finishing	3.19	18.90	9.79	6.58	5
8. Nonwoven Manufacturing	-	-	-	-	0
9. Felted Fabric Processing	-	-	-	-	0

TABLE B-2 (Cont.)

Subcategory	Total Chromium, ug/l				
	Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	-	-	37	-	1
2. Wool Finishing	24	366	195	195	2
3. Low Water Use Processing	-	-	60	-	1
4. Woven Fabric Finishing					
a. Simple Processing	14	182	42	20	7
b. Complex Processing	8	118	52	27	5
c. Complex Processing Plus Desizing	1	11600	1000	29	12
5. Knit Fabric Finishing					
a. Simple Processing	1	100	44	58	7
b. Complex Processing	15	100	46	25	3
c. Hosiery Products	-	-	30	-	1
6. Carpet Finishing	17	45	28	25	4
7. Stock & Yarn Finishing	14	265	97	42	5
8. Nonwoven Manufacturing	-	-	-	-	0
9. Felted Fabric Processing	-	-	-	-	0

TABLE B-2 (Cont.)

Subcategory	Total Chromium, g/kkg of Production				
	Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	-	-	2.15	-	1
2. Wool Finishing	12.34	176.18	94.26	94.26	2
3. Low Water Use Processing	-	-	-	-	0
4. Woven Fabric Finishing					
a. Simple Processing	1.21	37.17	8.28	2.61	7
b. Complex Processing	1.42	32.89	11.66	3.70	5
c. Complex Processing Plus Desizing	0.08	106.56	12.04	2.45	12
5. Knit Fabric Finishing					
a. Simple Processing	0.12	13.71	5.20	5.74	7
b. Complex Processing	1.13	19.10	7.37	1.90	3
c. Hosiery Products	-	-	1.24	-	1
6. Carpet Finishing	0.82	5.81	2.37	1.43	4
7. Stock & Yarn Finishing	0.77	35.29	13.10	3.93	5
8. Nonwoven Manufacturing	-	-	-	-	0
9. Felted Fabric Processing	-	-	-	-	0

TABLE B-2 (Cont.)

Subcategory	Sulfide, ug/l Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	-	-	365	-	1
2. Wool Finishing	-	-	-	-	0
3. Low Water Use Processing	32	148	90	90	2
4. Woven Fabric Finishing					
a. Simple Processing	57	200	128	128	2
b. Complex Processing	28	133	73	60	5
c. Complex Processing Plus Desizing	224	1610	1020	1120	4
5. Knit Fabric Finishing					
a. Simple Processing	73	1110	324	126	5
b. Complex Processing	10	100	55	55	2
c. Hosiery Products	-	-	56	-	1
6. Carpet Finishing	60	67	63	63	2
7. Stock & Yarn Finishing	27	185	111	116	4
8. Nonwoven Manufacturing	-	-	-	-	0
9. Felted Fabric Processing	-	-	-	-	0

TABLE B-2 (Cont.)

Subcategory	Sulfide, g/kkg of Production				
	Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	-	-	20.73	-	1
2. Wool Finishing	-	-	-	-	0
3. Low Water Use Processing	0.62	0.82	0.72	0.72	2
4. Woven Fabric Finishing					
a. Simple Processing	8.93	24.24	16.58	16.58	2
b. Complex Processing	3.74	27.57	12.09	9.60	5
c. Complex Processing Plus Desizing	33.57	155.93	93.53	92.31	4
5. Knit Fabric Finishing					
a. Simple Processing	5.75	78.40	27.75	20.79	5
b. Complex Processing	0.75	19.10	9.92	9.92	2
c. Hosiery Products	-	-	2.33	-	1
6. Carpet Finishing	1.82	8.48	5.15	5.15	2
7. Stock & Yarn Finishing	1.46	29.67	13.82	12.07	4
8. Nonwoven Manufacturing	-	-	-	-	0
9. Felted Fabric Processing	-	-	-	-	0

TABLE B-2 (Cont.)

Subcategory	Color, APHA Units				
	Min.	Max.	Avg.	Med.	No.
1. Wool Scouring	-	-	1890	-	1
2. Wool Finishing	-	-	-	-	0
3. Low Water Use Processing	-	-	-	-	0
4. Woven Fabric Finishing					
a. Simple Processing	-	-	337	-	1
b. Complex Processing	-	-	-	-	0
c. Complex Processing Plus Desizing	-	-	118	-	1
5. Knit Fabric Finishing					
a. Simple Processing	52	321	186	186	2
b. Complex Processing	-	-	-	-	0
c. Hosiery Products	-	-	-	-	0
6. Carpet Finishing	-	-	309	-	1
7. Stock & Yarn Finishing	225	719	472	472	2
8. Nonwoven Manufacturing	-	-	-	-	0
9. Felted Fabric Processing	-	-	-	-	0

APPENDIX C

PRIORITY POLLUTANTS

TABLE C-1 - LIST OF 129 PRIORITY POLLUTANTS

TABLE C-2 - TOXIC POLLUTANTS DETECTED IN TREATED EFFLUENT ABOVE THE NOMINAL DETECTION LIMITS

APPENDIX C-1

TOXIC POLLUTANTS

1. acenaphthene
2. acrolein
3. acrylonitrile
4. benzene
5. benzidine
6. carbon tetrachloride (tetrachloromethane)
7. chlorobenzene
8. 1,2,4-trichlorobenzene
9. hexachlorobenzene
10. 1,2-dichloroethane
11. 1,1,1-trichloroethane
12. hexachloroethane
13. 1,1-dichloroethane
14. 1,1,2-trichloroethane
15. 1,1,2,2-tetrachloroethane
16. chloroethane
17. bis(chloromethyl) ether
18. bis(2-chloroethyl) ether
19. 2-chloroethyl vinyl ether (mixed)
20. 2-chloronaphthalene
21. 2,4,6-trichlorophenol
22. parachlorometa cresol
23. chloroform (trichloromethane)
24. 2-chlorophenol
25. 1,2-dichlorobenzene
26. 1,3-dichlorobenzene
27. 1,4-dichlorobenzene
28. 3,3-dichlorobenzidine
29. 1,1-dichloroethylene
30. 1,2-trans-dichloroethylene
31. 2,4-dichlorophenol
32. 1,2-dichloropropane
33. 1,3-dichloropropylene
34. 2,4-dimethylphenol
35. 2,4-dinitrotoluene
36. 2,6-dinitrotoluene
37. 1,2-diphenylhydrazine
38. ethylbenzene
39. fluoranthene
40. 4-chlorophenyl phenyl ether
41. 4-bromophenyl phenyl ether
42. bis(2-chloroisopropyl) ether
43. bis(2-chloroethoxy) methane
44. methylene chloride (dichloromethane)
45. methyl chloride (chloromethane)

46. methyl bromide (bromomethane)
47. bromoform (tribromomethane)
48. dichlorobromomethane
49. trichlorofluoromethane
50. dichlorodifluoromethane
51. chlorodibromomethane
52. hexachlorobutadiene
53. hexachlorocyclopentadiene
54. isophorone
55. naphthalene
56. nitrobenzene
57. 2-nitrophenol
58. 4-nitrophenol
59. 2,4-dinitrophenol
60. 4,6-dinitro-o-cresol
61. N-nitrosodimethylamine
62. N-nitrosodiphenylamine
63. N-nitrosodi-n-propylamine
64. pentachlorophenol
65. phenol (4APP)
66. bis(2-ethylhexyl) phthalate
67. butyl benzyl phthalate
68. di-n-butyl phthalate
69. di-n-octyl phthalate
70. diethyl phthalate
71. dimethyl phthalate
72. benzo(a)anthracene (1,2 benzanthracene)
73. benzo(a)pyrene (3,4-benzopyrene)
74. 3,4-benzofluoranthene
75. benzo(k)fluoranthane(11,12-benzofluoranthene)
76. chrysene
77. acenaphthylene
78. anthracene
79. benzo(ghi)perylene (1,12-benzoperylene)
80. fluorene
81. phenanthrene
82. 1,2,5,6-dibenzanthracene
83. indeno (1,2,3-cd) pyrene
84. pyrene
85. tetrachloroethylene
86. toluene
87. trichloroethylene
88. vinyl chloride (chloroethylene)
89. aldrin
90. dieldrin
91. chlordane (tech. mixture & metabolites)
92. 4,4'-DDT
93. 4,4'-DDE (p,p'-DDX)
94. 4,4'-DDD (p,p'-TDE)

95. alpha-endosulfan
96. beta-endosulfan
97. endosulfan sulfate
98. endrin
99. endrin aldehyde
100.heptachlor
101.heptachlor epoxide
102.alpha-BHC
103.beta-BHC
104.gamma-BHC (lindane)
105.delta-BHC
106.PCB-1242 (Arochlor 1242)
107.PCB-1254 (Arochlor 1254)
108.PCB-1221 (Arochlor 1221)
109.PCB-1232 (Arochlor 1232)
110.PCB-1248 (Arcohlor 1248)
111.PCB-1260 (Arochlor 1260)
112.PCB-1016 (Arochlor 1016)
113.Toxaphene
114.Antimony (Total)
115.Arsenic (Total)
116.Asbestos (Fibrous)
117.Beryllium (Total)
118.Cadmium (Total)
119.Chromium (Total)
120.Copper (Total)
121.Cyanide (Total)
122.Lead (Total)
123.Mercury (Total)
124.Nickel (Total)
125. Selenium (Total)
126.Silver (Total)
127.Thallium (Total)
128.Zinc (Total)
129.2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)

TABLE C-2

TOXIC POLLUTANTS DETECTED IN TREATED EFFLUENT ABOVE THE NOMINAL DETECTION LIMIT

acrylonitrile
benzene
1,2,4-trichlorobenzene
2,4,6-trichlorophenol
parachlorometacresol
chloroform
1,2-dichlorobenzene
ethylbenzene
trichlorofluoromethane
naphthalene
N-nitrosodi-n-propylamine
pentachlorophenol
phenol
bis(2-ethylhexyl) phthalate
tetrachloroethylene
toluene
trichloroethylene
antimony
arsenic
cadmium
chromium
copper
cyanide
lead
mercury
nickel
selenium
silver
zinc

APPENDIX D

TOXIC POLLUTANT SAMPLING AND ANALYTICAL PROCEDURES

The screening sampling, verification sampling, and analyses performed in connection with the review of the effluent limitations guidelines, new source performance standards, and pretreatment standards for the Textile Mills Point Source Category, were according to the EPA protocol, "Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants," dated March, 1977. The procedures employed are described below.

SAMPLING PROCEDURES

Collection Technique

Wastewater samples were collected by composite and grab sampling techniques. Composite samplers (Isco Model 1680) were used to collect raw waste and secondary effluent samples for analysis of nonvolatile organics and metals.

Tygon sample tubing used was washed with detergent, rinsed thoroughly, and given a final washing with organic-free water. A 1-liter sample blank was then collected and analyzed for organic leachates. Organic-free water was prepared by passing water, distilled in glass, through a 0.6-meter-long activated cargon column. The blank was collected in glass, sealed with a Teflon-lined cap, and stored in ice at 4°C until analyzed.

Grab sampling techniques were used to collect raw waste samples for other analyses, and for secondary effluent samples at some mills. Eight individual grap samples were collected at equally spaced time intervals during the normal working day. To insure that each of the eight laboratories received a sufficient portion of the same sample, grab samples were collected in a Teflon-lined, 10-liter stainless steel bucket. A specified aliquot was transferred to each of the sample bottles from this container. Care was taken to insure that the sample remained homogeneous throughout each of the 10-min pouring sessions. Containers for volatile organics analysis were collected and sealed first to minimize possible evaporation losses.

Sample Container Preparation

All glass containers were thoroughly cleaned with strong acid (50% sulfuric acid + 50% nitric acid), rinsed, and heated in a glass annealing oven at 400°C for at least 30 minutes. The rest of the glass containers were rinsed with methylene chloride and dried in the oven at 100°C. All glass bottles had Teflon-lined caps.

Plastic sample containers were thoroughly cleaned before use. Each bottle was washed with detergent and tap water, then rinsed with 1:1 nitric acid/tap water, 1:1 hydrochloric acid/tap water, and, finally, deionized distilled water.

Sampling Logistics

The type and volume of sample container varied, depending on the analysis to be made. Some samples required the addition of chemical preservatives in the field to prevent deterioration during shipment to the laboratory. A field sampling instructional worksheet was designed to facilitate the arduous task of filling bottles of different sizes requiring different sample volumes and preservatives at each location. Each sampling day, before sampling, bottle labels were filled out and affixed to the appropriate sample bottles.

Sample Shipping Procedure

Each bottle was capped and sealed with tape to prevent leakage. Glass bottles were individually wrapped to prevent breakage. Sample bottles were then packed in one-piece, molded, styrene foam shipping cartons with 3.8-cm walls and fitted tops. Each such unit was then placed in a corrugated cardboard box. Each carton was half-filled with sample bottles, filled with ice, sealed with celophane tape, and reinforced with 0.05-meter duct tape. Address labels were affixed to box tops and warning labels--"This Carton Contains Glass and Ice"--"Hold at airport and call _____" messages were also put on the box tops.

All samples were shipped by conventional air freight on the day that they were collected. The airlines selected offered the most direct route without carrier changes.

WASTEWATER CHEMICAL ANALYSES

Effluent Guidelines Conventional and Non-Conventional Pollutants

Parameters determined under the category of effluent guidelines conventional and non-conventional pollutants were: 5-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), color, sulfides, total suspended solids (TSS), pH, and total phenol. As sample shipments arrived at the lab, they were logged in and distributed to the designated technicians for analysis.

Conventional and non-conventional pollutants were determined on the raw waste and secondary effluent streams from each of the treatment plants samples by employing the procedures outline in "Standard Methods for the Examination of Water and Wastewater, 14th Edition."

Effluent values obtained from wastewater treatment facilities in some plants were greater than those of the influent raw waste. This occurred, in part, because the wastewater entered the treatment system 1 day to 5 days prior to leaving the treatment plant. The hydraulic retention time in textile wastewater treatment plants ranged from 1 day to 30 days, with an average value of 5 days.

Most of the textile mills samples had a secondary wastewater treatment facility that included a lagoon with several surface aerators, followed by a clarifier. Several mills used equalization basins prior to the aerated lagoons. Effluent samples were collected between the clarifier and the polishing pond in treatment plants that had both. There were two exceptions to this procedure however. At one mill, the effluent sample was taken after the polishing pond, and at another mill the effluent sample was inadvertently collected between the aerated lagoon and the settling basin. All other effluent samples were collected after the clarifiers.

Analysis Protocol For The 129 Consent Decree Toxic Pollutants

Recommended analytical procedures developed by EPA were used throughout this project. It is important to realize that these procedures were still under development and require further verification and validation. Therefore, the data generated as a result of the utilization of these procedures only serve to identify which of the 129 chemical species are present and to indicate the general concentration ranges within an order of magnitude.

Adaptations of these procedures to accommodate the special requirements of textile wastewaters and/or any ambiguities in analytical techniques are discussed below. Three chemical species were not determined in this project: endrin aldehyde, 2,3,7,8-tetrachlorodibenzo-q-dioxin (TCDD), and asbestos. EPA-Environmental Monitoring and Support Laboratory (EMSL) recommended that TCDD should be omitted because of its extreme toxicity, and the potential health hazard involved in preparing standard solutions from the pure compound. Pure endrin aldehyde could not be obtained in time to prepare standard solutions. Asbestos was eliminated, as recommended by EPA-IERL-RTP and EPA-EGD, due to the presence of other fibrous materials in textile wastewaters.

The analytical protocol divides the 129 chemical species into three basic categories: volatile organics, nonvolatile organics, and metals. The following sections outline the analytical procedures and modifications for each category.

Volatile Organics. The recommended analytical method was designed to determine those chemical species that are amenable to the Bellar purge and trap method. Eight 40-ml, hermetically sealed glass vials, stored in ice, were sent to the laboratory from each sampling site. The vials were composited within 1 day of receipt at the laboratory. Two vials of composite solution were sealed and retained at 4°C as reserve samples. Volatiles from 5-ml samples of composite solution were sparged with helium onto two Tenax GC-silica-packed sample tubes. (Internal standards were added to the solutions in the later stages of the program. The majority of the samples had been sparged and stored before the protocol was received and appropriate internal standard could be obtained.) The second Tenax tube was used as a backup sample. Tenax tubes were sealed under a nitrogen atmosphere in glass tubes and stored in a freezer at -18°C until analyzed.

Analyses were carried out using a Hewlett Packard 5981 GC-Mass Spectrometer with 5934 Data System. Sample tubes were heated to 180°C over a 1-min period and held at that temperature for 4 min to desorb the compounds onto a Carbowax 1500 column held at -40°C. Cryogenic trapping at -40°C (liquid nitrogen cooling) gave better reproducibility of retention time than using the suggested temperature of 30°C, for compounds with boiling points below room temperature. After desorption, the GC column temperature was raised 3°C/min to 170°C.

The mass spectrometric analysis method involves fragmentation of molecules using electron bombardment (70 eV). Masses and relative intensities of the most characteristic molecular fragments for each compound are listed in the protocol. The population of ion fragments covering the mass range from 35 atomic mass units to 500 atomic mass units was measured every 6 sec, and the data were stored on magnetic tape.

These data allow the operator to reconstruct chromatograms of observed intensity for an individual mass during the course of the scanning. Specific molecules may be detected in the presence of other compounds by examining the reconstructed intensity time plots of their characteristic masses.

Qualitative identification of a compound was made using the three criteria listed in the protocol: 1) retention time must coincide with known retention times, 2) the three characteristic masses must elute simultaneously, and 3) intensities of the characteristic masses must stand in the known proper proportions.

Quantitation of volatile organics was initially made using peak area counts and concentration calibration curves. Later in the program, response ratios using the 1,4-dichlorobutane internal standard were used in quantifying the concentrations. Base/neutral and acid organic compounds were quantified using deuterated anthracene and response ratios as prescribed in the protocol.

Nonvolatile Organics. This method determined the nonvolatile solvent-extractable organic compounds that could be analyzed by gas chromatographic methods. The 129 concent decree toxic pollutants contain 81 organic compounds classified as nonvolatile organics.

Nonvolatile organics are divided into three groups: base/neutral fraction, acid fraction (phenols), and pesticides and polychlorinated biphenyls (PCB).

The sample solution, 2 liters, was made alkaline (pH greater than 11) with sodium hydroxide, and then extracted three times with methylene chloride. Textile raw waste and effluent samples formed strong emulsions upon extraction with methylene chloride. The problem was resolved by drawing off small amounts of separated solvent and pouring the extract through the sample in the separatory funnel. Separation was also enhanced by slowly dripping the emulsion onto the wall of a slightly tilted flask. This approach gives better separation by providing a greated surface area for the solvent and water fractions. Some samples required centrifugation at 1,500 rpm for 1 hr to break the emulsion.

Extracts were dried on a column of anhydrous sodium sulfate, concentrated to 1 milliliter in a Kuderna-Danish (K-D) evaporator with a Snyder column spiked with deuterated anthracene, sealed in septum capped vials, and stored at 4°C until analyzed. Analyses were preformed on the GC/MS system using SP-2250 and Tenax GC columns for base/neutral and acid samples, respectively.

A separate 1 liter sample was used for analysis of the pesticides and PCB (Aroclor fluids). These compounds were extracted with a 15 percent methylene chloride and 85 percent hexane solvent mixture. The aqueous phase was discarded, and the organic phase was analyzed by GC with an electron capture detector. Where necessary, acetonitrile partitioning and a Florisil chromatography column were used for further cleanup of the sample. In 85 percent of the samples, additional cleanup was not required.

Confirmation of identity and quantitation were made using two different GC columns: SP-2550 and Dexil 410. Compound verification was made with the MS when the concentration was greater than 10 ug/l. Concentrations of pesticides ranged from 0.1 ug/l to 10 ug/l; therefore, MS verification was not possible in this study.

Metals. In addition to the volatile and nonvolatile organics, the 129 chemical species include 13 metals, asbestos, and cyanide. Each metal is measured as the total metal. Asbestos was not determined in this study; cyanide was measured by conventional wet chemistry techniques outline in "Standard Methods for the Examination of Water and Wastewater, 14th Edition."

Eight metals were analyzed by the inductively coupled argon plasma (ICAP) excitation technique: antimony, cadmium, chromium, copper, lead, nickel, silver, and zinc. Five metals were measured by conventional atmoic absorption techniques: arsenic, beryllium, mercury, selenium, and thallium.

ICAP forms an analytical system for simultaneous multi-element determinations of trace metals at the sub-ppm level in solutions. The basis of this method is atomic emission. Exicitation energy is supplied by coupling a nebulized sample with high temperature argon gas which has been passed through a powerful radio-frequency field. Emitted light is simultaneously monitored at 22 wavelengths corresponding to 22 different elements.

All samples for metals analysis were acidified in the field by adding 5 ml of redistilled nitric acid to each 10 liters of sample. Nitric acid blanks were also analyzed for metals.

APPENDIX E

SUPPORTING INFORMATION ON THE PRESENCE OR ABSENCE OF TOXIC POLLUTANTS IN TEXTILE MILL WASTEWATERS AND TEXTILE DYES FROM THE AMERICAN TEXTILE MANUFACTURERS INSTITUTE (ATMI) AND THE DYES ENVIRONMENTAL AND TOXICOLOGY ORGANIZATION (DETO).

AMERICAN TEXTILE MANUFACTURERS INSTITUTE, INC.

CHARLOTTE
WASHINGTON
NEW YORK

WACHOVIA CENTER, 400 S. TRYON ST., CHARLOTTE, N. C. 28285
TELEPHONE (704) 334-4734

May 15, 1978

Dr. James C. Buzzell, Jr.
Sverdrup & Parcel & Associates, Inc.
800 North Twelfth Blvd.
St. Louis, Missouri 63101

Dear Jim:

Our special Task Group on Priority Pollutants recently completed a further assessment of your findings on the presence or absence of priority pollutants in textile plant waste waters identified under list C -- presence in textile water not yet defined. Their preliminary findings were included in my letter to you dated December 29, 1977.

Following that preliminary review, the task group further classified the pollutants in Text C as Probable, Possible or Not Likely to be found in textile effluent. Their basis ~~for this classification was:~~

Probable -- definitely established as present in a product or process. Pollutant levels have been established in only a few cases but the evidence is sound.

Possible -- known or suspected as an intermediate or contaminant of products and processes being used. Many in this category could be entering in an auxiliary manner such as maintenance products and agricultural contaminants in process water.

Not Likely -- unable to find data to support the presence of these chemicals.

Using this rationale, the task group considered each of the compounds on your List C, classified it according to the above definitions and attempted to identify the source and relative amount of the compound. This information is included in the attached table.

We feel this is our best assessment of these chemicals in textile waste waters and that further investigation would be somewhat meaningless until we have some indication of the tolerance levels and/or parameters that may or may not be acceptable. We hope that this information will be of some significant use to you in preparation of your final report which we understand is due in June.

Sincerely,

O'Jay Niles

dgb

cc: Dr. Jim Gallup
Mr. Wallace Storey

SVERDRUP AND PARCEL LIST C

CLASSIFICATION BY

ATMI PRIORITY POLLUTANT TASK GROUP

No.	NAME	PRESENCE	SOURCE AND AMOUNT
9.	Hexachlorobenzene	Possible	Industrial cleaner or preservative
10.	1,2-dichloroethane	Probable	Spot cleaners
13.	1,1-dichloroethane	Not Likely	Chemically unstable
14.	1,1,2-trichloroethane	Possible	Cleaning products
17.	bis (chloromethyl)ether	Not Likely	Chemically unstable
21.	2,4,6-trichlorophenol	Possible	Preservative
22.	parachlorometacresol	Possible	Industrial cleaner
24.	2-chlorophenol	Not Likely	
27.	1,4-dichlorobenzene	Possible	Contaminant of Dyes or Agricultural use
28.	3,3-dichlorobenzidine	Probable	0.75 ppm--5 ppm in pigment being used for printing applications
34.	2,4-dimethylphenol	Possible	Dye Carriers
36.	2,6-dinitrotoluene	Possible	Manufacture of Sulpher Dye
37.	1,2-diphenylhydrazine	Possible	Laboratory chemical
40.	4-chlorophenyl phenyl ether	Possible	Industral cleaning
44.	methylene chloride	Possible	Solvent formulations--small amounts
45.	methyl chloride	Possible	Contaminant 1ppb
46.	methyl bromide	Not Likely	
49.	trichlorofluoromethane	Possible	Refrigerant
50.	dichlorodifluoromethane	Possible	Refrigerant
52.	hexachlorobutadiene	Not Likely	

NAME	PRESENCE	SOURCE AND AMOUNT
isophorone	Possible	Contaminant
4,6-dinitro-o-cresol	Possible	Agricultural use
N-nitrosodimethylamine	Possible	Contaminant
N-nitrosodiphenylamine	Possible	Contaminant
N-nitrosodi-n-propylamine	Possible	Contaminant
bis-(2-ethylhexyl) phthalate	Probable	Common Plasticizer-likely present 10-50% in some coating formulations
di-n-butyl phthalate	Probable	Common Plasticizer-likely present 10-50% in some coating formulations
diethyl phthalate	Probable	Common Plasticizer-likely present 10-50% in some coating formulations
fluorene	Probable	Sanitary Cleaners L.T. 0.1%
1,2:5,6-dibenzanthracene	Not Likely	
pyrene	Not Likely	
chlordane	Possible	Agricultural use
4,4' -DDT	Possible	Agricultural use
4,4' -DDE (p,p'-DDX)	Possible	Agricultural use
4,4' -DDD (p,p' -TDE)	Possible	Agricultural use
a-endosulfan	Possible	Agricultural use
b-endosulfan	Possible	Agricultural use
endrin	Possible	Agricultural use
heptachlor	Possible	Agricultural use
heptachlor epoxide	Possible	Agricultural use
-BHC	Possible	Agricultural use
-BHC	Possible	Agricultural use
-BHD (lindane)	Possible	Agricultural use
-BHC	Possible	Agricultural use

No.	NAME	PRESENCE	SOURCE AND AMOUNT
110.	arsenic	Probable	Fungicides-Dyes-Specialt Chemicals up to 4 ppm
111.	asbestos	Possible	Filters, Pipe Wrappers a Heat Shields
112.	beryllium	Probable	Specialty Chemicals up t 3 ppm
116.	cyanide	Probable	Laboratory and Specialty Chemicals up to 3%
118.	mercury	Probable	Dyes up to 2 ppm Specialty Chemicals up t 50 ppm
120.	selenium	Probable	Dyes up to 5 ppm Specialty Chemicals up t 10 ppm
121.	silver	Probable	Dyes up to 5 ppm Specialty Chemicals up t 10 ppm
122.	thallium	Possible	Contaminant

AMERICAN TEXTILE MANUFACTURERS INSTITUTE, INC.

CHARLOTTE
WASHINGTON
NEW YORK

WACHOVIA CENTER, 400 S. TRYON ST., CHARLOTTE, N. C. 28285
TELEPHONE (704) 334-4734

December 29, 1977

Dr. James C. Buzzell, Jr.
Sverdrup & Parcel & Associates, Inc.
800 North 12th Boulevard
St. Louis, Missouri 63101

Dear Jim:

Back in September you wrote Wallace Storey with results of your findings on the presence or absence of priority pollutants in textile plant wastewaters. You asked for our review and comments on your assignment of those pollutants in three lists, especially List C.

Such an assessment is beyond the expertise of our Environmental Preservation Committee and a special Task Group on Priority Pollutants was organized to review List C and to develop appropriate comments. They have completed a preliminary assessment and we are pleased to enclose a summary of their comments.

The task group is doing some additional work in trying to answer more of the specific questions you posed in your letter to Wallace and we will pass that information on to you as it is developed; hopefully this will be about mid January.

We appreciate the opportunity to give you our views on this important work and hope to maintain close liaison as you move forward with your investigations. We're sorry this has taken a bit longer than we expected but the issues are so important that we want to do a thorough job and it's necessary to work with others outside the Environmental Preservation Committee.

Best wishes for the New Year,

O'Jay Niles

OJN/lhb

CC: Wallace Storey

PRELIMINARY REVIEW OF S & P's CLASSIFICATION OF PRIORITY POLLUTANTS - LIST C, PRESENCE IN TEXTILE WASTEWATER NOT YET DEFINED

Submitted by American Textile Manufacturers Institute

GENERAL COMMENTS:

1. The characteristics of incoming water must be identified; this seems to be a potential source of more than half of the items on List C, also the persistency of environmental contaminants, especially in agricultural areas, can be of indefinite terms.

2. None of the materials on List C are primary processing chemicals in textile finishing.

3. Some materials could be present as contaminants of primary processing products, such as dyestuffs and auxiliaries.

4. Some materials on List C could be present as contaminants of raw materials, such as fibers.

5. Some materials on List C could be from maintenance and housekeeping practices within the plant, directly, or as contaminants of products used.

6. There is some question as to the accuracy of the most up-to-date analytical procedures in the very small quantities being considered, which is just what we talked about at the table. That's the analytical chemists not being willing to say there is nothing there. They are not even willing to say there is something there.

SPECIFIC COMMENTS:

Item No.	Priority Pollutant	Comments
9.	hexachlorobenzene	A fungicide and not a direct processing chemical, but may be used in industrial cleaning compounds; possibility of trace amounts of specialty chemicals.
10.	1,2 - dichloroethane	A solvent for fats, oils and waxes, commonly used with epoxy formulations, might be in spot removers and remain in trace amounts on fabric.
13.	1,1 - dichloroethane	Chemically unstable with hydrolyzing water to acid aldehyde and hydrochloric acid. No specific use in textile processing.
14.	1,1,2 - trichloroethane	Solvent for fats, waxes and alcoloids, may be present in scouring products or spot removers.
17.	bis(chloromethyl) ether	Hydrolyzes rapidly in water, it has been studied by NIOSH and not shown to be present in processing or waste streams.
21.	2,4,6 - trichlorophenol	A fungicide, bactericide and preservative. Dowcide 2F. Possible contaminant in specialty chemicals.

Item No.	Priority Pollutant	Comments
22.	parachlorometacresol	Antiseptic and disinfectant, possibly in industrial cleaning agents.
24.	2 - chlorophenol	Bactericide, possible fungicide, might be used in the manufacture of dyes.
27.	1,4 - dichlorobenzene	An insecticide used in mothballs, suggest possibility of contamination of incoming water from agricultural use, possibly found in carriers.
28.	3,3 - dichlorobenzidine	May be used in azo dyes: trace contaminants at a very low level.
34.	2,4 - dimethylphenol	An insecticide, fungicide, plasticizer, additive to lubricants and gasoline. Suggest non-process use in contamination. Had been used in dye carriers.
36.	2,6 - dinitrotoluene	Possible use in dyestuff manufacture, mild oxidizing agent in dye testing operations.
37.	1,2 - diphenylhydrazine	Impurity in azo dyestuff, limited use in textile laboratories.
40.	4 - chlorophenyl phenyl ether	Fungicide, bactericide and lysol, or an ingredient of lysol.
44.	methylene chloride	Solvent in binders, cleaning and degreasing products, machine oils and spot removers.
45.	methyl chloride	Extremely volatile, possibly in the aerosol propellants.
46.	methyl bromide	Soil fumigant, using flammability control of methyl chloride, so it is also possible in the aerosol propellant.

Item No.	Priority Pollutant	Comments
49.	trichlorofluoromethane	Common refrigerant, Freon, possible aerosol propellant, non-processing use in textile plants.
50.	dichlorodifluoromethane	Same as No. 49.
52.	hexachlorobutadiene	Rubber solvent.
54.	isophorone	Solvent for vinyl resins and other synthetic resins, possible condensation product is applicable.
60.	4, 6 - dinitro-o-cresol	Insecticide, herbicide used on peach trees.
61.	N - nitrosodimethylamine	Relatively unstable compound and possible dyestuff constituent.
62.	N - nitrosodiphenylamine	An accelerator in vulcanizing rubber, possible contaminant from equipment and/or dyestuff.
63.	N - nitrosodi-n-propylamine	Possibly a dyestuff contaminant.
66.	bis (2 - ethylhexyl) phthalate	A common plasticizer for vinyls, cellulose and acrylic resins. Possibly a product of a reaction between trimer and polyester and ethylhexyl-alcohol which is a common antifoam.
68.	di-n-butyl phthalate	A plasticizer, possibly found in speciality machine oils and lubricants or in dye carriers, also in insecticides.
69.	diethy phthalate	Same as No. 68.
79.	fluorene	An insecticide which is present in coal tar products up to 2% and possible in some sanitary cleaning agents.

Item No.	Priority Pollutant	Comments
81.	1, 2, 5, 6 - dibenzanthracene	Unknown.
83.	pyrene	Present in fire extinguishers.
91.	chlordane	Nos. 91 through 105 are insecticides. Plant entry with raw materials or process water possible. Could be used as insect control. They could be contamination from ground water or possible insect control in factories.
92.	4, 4' - DDT	
93.	4, 4' - DDE (p, p' - DDX)	
94.	4, 4' - DDD (p, p' - TDE)	
95.	a - endosulfan	No. 100 is a fungicide and it is listed as control of boll weevil in cotton.
96.	b - endosulfan	
98.	endrin	
100.	heptachlor	
101.	heptachlor epoxide	
102.	- BHC	
103.	- BHC	
104.	- BHD (lindane)	
105.	- BHC	
110.	arsenic	An impurity in pigments, it could be a trace in polyester due to a catalyst in synthesis. It is a rodenticide and is used in the manufacture of glass.
111.	asbestos	The presence of this might be from a final product rather than a processing material in plants where they use asbestos and fibers and they make an asbestos fabric, or from filters, insulation, internal or external pipe wrapping, or heat shields.

Item No.	Priority Pollutant	Comments
112.	beryllium	An ingredient of ceramics and fiber glass. That's all we found on that one.
116.	cyanide	The most likely place for contamination, if any, would be laboratory waste.
118.	mercury	Could be an impurity in azo dyestuff or residue from catalyst in synthesis of various chemicals, or as a fungicide. It is an ingredient of some older fungicides.
120.	selenium	Used in rubber processing, photography baths, pigments used for coloring glass and also in laboratory work.
121.	silver	Could be a trace from silver nitrate either used in processing or in laboratory work, or it could be a residue of catalyst again from previous organic synthesis.
122.	thallium	Could be residue from catalyst or rodenticide.

Following pollutants were not classified by S & P: assignment to one of the three lists is requested as soon as possible:

No. 69 di-n-octyl phthalate

108 PCB-1221

109 PCB-1232

110 PCB-1248

111 PCB-1260

112 PCB-1016

deto DYES ENVIRONMENTAL AND TOXICOLOGY ORGANIZATION, INC.
1075 CENTRAL PARK AVENUE, SCARSDALE, N.Y. 10583 • (914) 725-1492

April 19, 1978

Dr. James D. Gallup
United States Environmental Protection Agency
Effluent Guidelines Division (WH-552)
401 M Street, SW
Washington, D. C. 20460

Dear Dr. Gallup:

Since our recent attempts to communicate by telephone were unsuccessful, I have elected to write concerning the DETO study of "Priority Pollutants" believed to be present in large volume commercial dye products. We believe the report will be useful in your development of guidelines for the textile industry. A copy of the report is enclosed.

We would welcome the opportunity to meet with you to discuss the report and to answer questions which you or your contractor may raise. Such a meeting, which would include several members of the DETO Ecology Committee, could be scheduled during the latter part of May. Please suggest two dates as early as May 18, 1978.

Very truly yours,

William Allen

William Allen, Chairman
Ecology Committee of DETO

WA/pmk
Enclosure

cc: Mr. Richard Hinds
Dr. Roderick H. Horning
Mr. Mark Thorn
Dr. Harshad Vyas

deto DYES ENVIRONMENTAL AND TOXICOLOGY ORGANIZATION, INC.
1075 CENTRAL PARK AVENUE, SCARSDALE, N.Y. 10583 • (914) 725-1492

October 17, 1978

Mr. James Buzzell
Sverdrup & Parcel And Associates, Inc.
800 North 12th Boulevard
St. Louis, MI 63101

Dear Jim:

My apologies for taking so long to write. The delay was, at least in part, caused by the fact that I have not located a spare copy of the AATCC Buyer's Guide.

I should also have thought of it earlier; however, the Buyer's Guide is available at $10.00 each from AATCC, Box 12215, Research Triangle Park, NC 27709.

Concerning the report provided to you earlier by DETO, I should like to ask that an additional statement be included at the end of the report. The report indicates concentrations of priority pollutants that may be found in dyes. Any one of these priority pollutants is, however, likely to be present in only a relatively few of the total number of dyes available. For example, there is a group of so-called coppered dyes that may contain up to 3-4% of copper, a substantial portion of which is exhausted onto the fabric. These are generally well known.

There is another group, also limited in number for which copper is used in the preparation and which may contain between 50 and 100 ppm copper. And finally, the remaining dyes (which I would guess to be as much as 85% or more of the total) that contain only tramp copper in the 1-2 ppm range. The data available at the present time does not permit us to be more specific concerning how many dyes of those reviewed fall into which class.

I trust that this additional information will be of value and that it will be incorporated into your final report. If I can provide additional information, please let me know.

Very truly yours,

Roderick H. Horning
Chairman, Technical Committee
DETO

RHH/cw

cc: W. Allen
S. Boyd
R. Hinds, S. Kasprzak

AFFILIATED WITH SYNTHETIC ORGANIC CHEMICAL MANUFACTURERS ASSOCIATION, INC.

REPORT ON SURVEY OF "PRIORITY POLLUTANTS" BELIEVED TO BE PRESENT IN LARGE VOLUME COMMERCIAL DYE PRODUCTS

APRIL 6, 1978

I. Introduction

At the request of the Environmental Protection Agency (EPA) the Dyes Environmental and Toxicology Association, Inc. (DETO)[1/] agreed to assist EPA in its efforts to evaluate the role of commercial dye products and certain "priority pollutants" therein, if any, in textile mill effluent. This report is the result of that effort.

II. Summary

This report and the underlying survey demonstrate that relatively few "priority pollutants" are likely to be present in large volume commercial dye products. Those that are likely to be present are likely to be present in small amounts which will not add significantly to the raw effluent wasteload of textile mills.

III. Background and Methodology

In early December 1977, shortly after having met with EPA representatives, DETO's Ecology Committee assembled to review how best to assist the EPA. After extended discussion, the Committee concluded that a survey of priority pollutants which might be present in large volume commercial dye products was the best means to accomplish the necessary objectives. Because of EPA's short regulatory timetable and the necessity for a quick response from DETO, the Committee decided to limit its survey to large volume commercial dye products and to eliminate from its survey those priority pollutants which it believed could not possibly be present in commercial dye products.

The Committee carefully reviewed each of EPA's priority pollutants and eliminated from the list those which it believed were not present in or

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1/ A short description of DETO, whose members account for over ninety percent of the dyes produced in the United States, is attached hereto as Appendix A.

formed during tne manufacturing process. Where the Committee was in doubt, the pollutant was not eliminated. This review resulted in 40 priority pollutants which the Committee believed could possibly be present in commercial dye products.[1/]

Once the pollutants to be surveyed were ascertained, the Committee excerpted from the International Trade Commission (ITC) report of 1976, dyes listed therein. The dyes selected from the ITC report are those for which domestic sales exceed 200,000 pounds per year and for which there are generally more than two producers.[2/] This list of dyes numbered 70.[3/]

A questionnaire was then prepared by the Ecology Committee (Appendix B) which asked member companies to indicate for which of the 70 ITC-listed commercial dye products any of the listed 40 priority pollutants were believed to be present and whether the amounts present were believed to be greater than or less than 0.1%.[4/] The questionnaire also solicited the same information for commercial dye products for which domestic sales exceeded 200,000 but which were produced by two or fewer producers or not otherwise listed in the ITC report.

IV. Responses

Responses were received by DETO from all eighteen member companies. In addition to the requested responses for the 70 dyes listed in the questionnaire, additional responses were received on 81 other dyes.[5/] The total

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1/ See the attached DETO questionnaire (Appendix B) for the list of the 40 priority pollutants surveyed.

2/ The ITC does not compile statistics on other producers or dyes because of confidentiality problems.

3/ See the attached DETO questionnaire (Appendix B) for the list of 70 dyes surveyed.

4/ No analytical laboratory work was requested of member companies.

5/ These dyes are not listed in the ITC report for confidentiality reasons.

survey thus covered 151 dyes which represent total sales of approximately 138.3 million pounds or 55.3 percent of the 250 million pounds sold in 1976.

Many of the dyes are produced by several companies and processes may differ. Therefore, independent evaluations were made for many dyes.

V. Results and their Significance

The survey demonstrates that relatively few priority pollutants are likely to be present in large volume commercial dye products. Those that are likely to be present are likely to be present in small amounts which will not add significantly to the raw effluent wasteload of textile mills.

The results of the survey indicate that only 25 priority pollutants were thought likely to be present in the 151 dyes surveyed. The majority of them, 19, were thought likely to be present below 0.1%. Only six were thought likely to be present in quantities greater than 0.1%.[1/] These six priority pollutants consist of three metals (copper, chromium and zinc) and three biocides (phenol, pentachlorophenol and parachlorometacresol). It should be emphasized that only a few of the many dyes surveyed were thought to contain any priority pollutants, and then only in these very small amounts.

Application of a dilution factor to the amount of pollutant thought likely to be present in the commercial dye product to reflect the dilution which might be expected in the effluent makes clear that the amount likely to be present in the raw effluent for any of the 25 pollutants is not likely to add significantly to the raw effluent wasteload. Wastewater treatment of effluent will, of course, reduce this amount even further.

A. Metals

The significance of metals in dyes has been the subject of a recent paper by Horning, Allen *et al.* for the American Dye Manufacturers Institute entitled "The Contribution of Dyes to the Metal Content of Textile Mill Effluent"

1/ The 25 pollutants are listed in Table I.

published in Journal of the American Association of Textile Chemists and Colorists, Vol. 4, p. 275 (December 1972) (Appendix C). This paper was based on actual analyses of dyes and their contribution to effluent wasteload. The results of the DETO survey confirm many of the conclusions reached in this paper. The following discussion draws heavily from this paper.

Copper and chromium are believed to be present in premetallized and coppered dyes frequently in the vicinity of 3 to 4%. These metals are an intergral part of certain dye molecules. Because these metals are a basic part of the dye, they exhaust onto the textile fiber with the dye. Approximately 95% is believed to so exhaust onto the fiber.[1/] The potential for exhaustion into the effluent is thus not likely to be more than 5% of the metal in the dye (i.e., 4%) or a total of .02%.

Zinc is believed to be present because a number of basic dyes are prepared as a double salt containing zinc. The zinc content of these dyes is frequently in the 3% range and is generally not exhausted onto the textile fiber with the dye.

B. Biocides

The amount of phenol, pentachlorophenol and parachlorometacresol in commercial dye products is believed to be in the approximate range of less than 0.1% to 0.5%.[2/] Fiber retention is not believed likely.

C. Dilution in Effluent

The considerable quantity of water generally used in the processing of textiles reduces the concentration of waste products, including pollutants

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1/ Bird, C.L., Theory and Practice of Wool Dying, 4th Edition, 1972, Society of Dyers and Colorists, p.104.

Kranrisch, B., "Methods of Assessing the Dying Properties of Wool Dyes" Journal of the Society of Dyers and Colorists, 75, p.242 (1959)

U.S. Patent 3,043,648, assigned to Sandoz

2/ Member company information

found in commercial dye products considerably. The above-referenced paper concludes that a dilution factor of 10,000 is a good approximation.

For those few pollutants believed to be present in quantities below 0.1%, the suggested dilution factor would result in a concentration of no more than 0.1 ppm in the untreated effluent.

For those six pollutants believed to be present in quantities of greater than 0.1%, the approximate range of concentration in the untreated effluent of selected dyes, based on the above figures, would appear to be as follows: copper, .02 ppm; chromium, .02 ppm; zinc, 3 ppm; biocides, .1 to 1 ppm.

Wastewater treatment would, of course, reduce these amounts even further.

TABLE I

PRIORITY POLLUTANTS BELIEVED PRESENT IN COMMERCIAL DYES AT LESS THAN 0.1%

acenaphthene	mercury
acrylonitrile	methyl bromide
anthracene	monochlorobenzene
arsenic	naphthalene
benzidine	nickel
cadmium	4-nitrophenol
1,2-dichlorobenzene	N-nitrosodimethylamine
2,4-dinitrophenol	phenanthrene
ethylbenzene	toluene
lead	

PRIORITY POLLUTANTS BELIEVED PRESENT IN COMMERCIAL DYES AT GREATER THAN 0.1%

chromium	pentachlorophenol
copper	phenol
parachlorometacresol	zinc

Appendix A

DETO was formally organized on May 11, 1977, to represent dyes producers in matters relating to the health and environmental impact of dyes manufacture, distribution, use and disposal. DETO's eighteen member companies account for over ninety percent of the dyes produced in the United States.

The following are DETO member companies:

American Color & Chemical Corporation
American Cyanamid Company
American Hoechst Corporation
Atlantic Chemical Corporation
BASF Wyandotte Corporation
Berncolors-Poughkeepsie, Inc.
Ciba-Geigy Corporation
Crompton & Knowles Corporation
E. I. du Pont de Nemours & Company
Eastman Chemical Products, Inc.
Fabricolor, Inc.
GAF Corporation
Harshaw Chemical Company
ICI Americas, Inc.
Otto B. May, Inc.
Martin Marietta Chemicals
Mobay Chemical Corporation
Sandoz Colors & Chemicals

deto DYES ENVIRONMENTAL AND TOXICOLOGY ORGANIZATION, INC.
1075 CENTRAL PARK AVENUE, SCARSDALE, N.Y. 10583 • (914) 725-1492

December 27, 1977

TO: OFFICIAL REPRESENTATIVES
ALTERNATES

EPA REGULATION OF TOXIC POLLUTANTS

We need your assistance on a project of considerable importance.

As many of you know, the Environmental Protection Agency (EPA) is in the process of developing effluent limitation regulations for the textile industry. Representatives from DETO's Water Subcommittee, of which I am chairman, have met with EPA to discuss the status of this project and, more specifically, the role that commercial dye products play in textile effluent. EPA has requested, and we have agreed, to attempt to obtain from DETO member companies information which will assist EPA in properly characterizing the dye-related pollutants in textile effluent. It is the view of the Subcommittee that this information will most likely demonstrate that there are few, if any, dyes which create problems in textile effluent. We believe that the dye industry by cooperating with the EPA and providing them with the requested information can better ensure reasonable regulation.

Enclosed is a questionnaire which we would like your company to complete and mail to Mark Thorn, DETO's Manager for Environmental Affairs, on or before January 16, 1978. EPA's schedule is such that responses from your company within this time frame or shortly thereafter are necessary.

The questionnaire is relatively simple to complete. Listed on the questionnaire are the major dyes domestically produced and sold, defined for purposes of this survey as those dyes reported in the 1976 International Trade Commission (ITC) Report for which annual sales exceed 200,000 pounds.*/ Attached to the questionnaire is a list of 40 numbered pollutants that the Subcommittee has determined could possibly be present in commercial dye products. The list was narrowed by the Subcommittee from a list of 129 pollutants designated by EPA as "priority pollutants" for regulatory purposes.

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*/ No distinction has at this juncture been made between dyes used in textile industries and those used in non-textile industries, primarily because of the scheduling constraints placed on us by EPA.

AFFILIATED WITH SYNTHETIC ORGANIC CHEMICAL MANUFACTURERS ASSOCIATION, INC.

DETO SURVEY OF PRIORITY POLLUTANTS BELIEVED TO BE PRESENT IN COMMERCIAL DYES

All responses will be treated confidentially. If you are concerned about the proprietary nature of any information you intend to submit, you may submit it to DETO counsel Eric Schwartz or Richard Hinds at Cleary, Gottlieb, Steen & Hamilton, 1250 Connecticut Avenue, N. W., Washington, D. C. 20036.

Directions

1. Complete company and company contact identification information.

2. Determine for each of your dyes listed below whether the pollutants listed on Attachment A hereto are believed to be present in commercial dye product (including adjuvants therein).*/

3. If one or more pollutants are believed to be present, please note below the pollutant number(s) designated for that pollutant in Attachment A and the quantity of pollutant believed to be present in the commercial product (more or less than one-tenth of one percent (0.1%). No analytical laboratory work is expected or required. You may attach additional sheets if necessary.

4. If there are commercial dyes of which you are aware which are sold in quantities in excess of 200,000 pounds per year that are not listed below**/ and which you manufacture, please determine whether any of the pollutants listed in Attachment A are present therein and, if so, in what quantities. Such information should be added to the end of the questionnaire using the same format as described earlier.

5. Complete questionnaires should be returned to Mark Thorn, DETO's Environmental Manager, at the DETO address. Questions about completing the questionnaire should be directed to Mark Thorn.

---

*/ The dyes listed on the questionnaire are those for which the 1976 International Trade Commission (ITC) Report reported sales in excess of 200,000 pounds annually.

**/ These would be dyes not listed in the ITC Report but for which sales nonetheless exceed 200,000 pounds per year.

Your company should review the dyes listed on the questionnaire to determine whether any of the numbered pollutants in the attached list appear in its commercial dye products (including adjuvants). If it is determined that one or more pollutants may be present in your company's dyes, you should indicate whether you believe the amount present in the commercial dye product is more or less than one-tenth of a percent (0.1%), i.e., 1000 ppm. In responding to this questionnaire no analytical laboratory work is requested or required.

If there are other dyes which your company manufactures for which total domestic sales (of all companies) exceeds 200,000 pounds per year that are not listed on the questionnaire because they are not included in the 1976 ITC Report, you should also examine whether any of the numbered pollutants appear in those commercial dye products.

All information submitted will be treated in confidence by DETO. No information related to a particular company will be disclosed, directly or indirectly, without that company's prior authorization. Further, if there is any information which you believe is proprietary in nature, you should feel free to submit such information to counsel Eric Schwartz or Richard Hinds at Cleary, Gottlieb, Steen & Hamilton.

Any questions on completing the questionnaire should be directed to Mark Thorn.

We will keep you apprised of the status of this project and will, of course, provide you with a copy of the submission to EPA which will be based on the data you have provided.

Your cooperation in this important project is very much appreciated.

Sincerely,

William Allen

William Allen
Chairman, Water Subcommittee

Enclosure

Questionnaire

Company Name: ____________________

Company Contact: ____________________

Name: ____________________

Address: ____________________

Phone: ____________________

Commercial Dye	Priority Pollutants Believed to be Present in Commercial Dye*	Estimated Quantity**	
		Less than 0.1%	More tha: 0.1%
Acid Yellow 23			
Acid Yellow 151			
Acid Yellow 159			
Acid Orange 7			
Acid Orange 8			
Acid Orange 10			
Acid Orange 24			
Acid Orange 60			
Acid Orange 116			
Acid Red 1			

*/ Insert pollutant numbers from Attachment A.

**/ Check appropriate column.

Commercial Dye	Priority Pollutants Believed to be Present in Commercial Dye	Estimated Quantity	
		Less than 0.1%	More th 0.1%
Acid Red 114	________ ________	____ ____	____ ____
Acid Red 151	________ ________	____ ____	____ ____
Acid Red 337	________ ________	____ ____	____ ____
Acid Blue 9	________ ________	____ ____	____ ____
Acid Blue 25	________ ________	____ ____	____ ____
Acid Blue 40	________ ________	____ ____	____ ____
Acid Blue 113	________ ________	____ ____	____ ____
Acid Black 52	________ ________	____ ____	____ ____
Acid Black 107	________ ________	____ ____	____ ____
Direct Yellow 106	________ ________	____ ____	____ ____
Direct Orange 15	________ ________	____ ____	____ ____
Direct Orange 72	________ ________	____ ____	____ ____
Direct Orange 102	________ ________	____ ____	____ ____
Direct Red 24	________ ________	____ ____	____ ____
Direct Red 72	________ ________	____ ____	____ ____

Commercial Dye	Priority Pollutants Believed to be Present in Commercial Dye	Estimated Quantity	
		Less than 0.1%	More than 0.1%
Direct Red 80			
Direct Red 81			
Direct Blue 1			
Direct Blue 2			
Direct Blue 80			
Direct Blue 86			
Direct Blue 218			
Direct Brown 95			
Direct Black 22			
Direct Black 38			
Disperse Yellow 3			
Disperse Yellow 23			
Disperse Yellow 42			
Disperse Yellow 54			
Disperse Orange 25			

Commercial Dye	Priority Pollutant Believed to be Present in Commercial Dye	Estimated Quantity	
		Less than 0.1%	More th 0.1%
Disperse Red 1			
Disperse Red 17			
Disperse Red 60			
Disperse Red 177			
Disperse Blue 3			
Disperse Blue 64			
Acid Black 1			
Azoic Diazo Component 9, salt			
Azoic Diazo Component 13, salt			
Basic Yellow 11			
Basic Yellow 13			
Basic Orange 2			
Basic Orange 21			
Basic Red 14			
Basic Red 18			
Basic Violet 1			

Commercial Dye	Priority Pollutant Believed to be Present in Commercial Dye	Estimated Quantity	
		Less Than 0.1%	More tha 0.1%
ɜasic Violet 16	________ ________	____ ____	____ ____
)irect Yellow 4	________ ________	____ ____	____ ____
)irect Yellow 6	________ ________	____ ____	____ ____
)irect Yellow 11	________ ________	____ ____	____ ____
)irect Yellow 44	________ ________	____ ____	____ ____
)irect Yellow 50	________ ________	____ ____	____ ____
)irect Yellow 84	________ ________	____ ____	____ ____
)isperse Blue 79	________ ________	____ ____	____ ____
Vat Yellow 2, 8-1/2%	________ ________	____ ____	____ ____
Vat Orange 2, 12%	________ ________	____ ____	____ ____
Vat Green 3, 10%	________ ________	____ ____	____ ____
Vat Black 25, 12-1/2%	________ ________	____ ____	____ ____
Vat Black 27, 12-1/2%	________ ________	____ ____	____ ____
Flourescent Brightening Agent 28	________ ________	____ ____	____ ____

ATTACHMENT A
LIST OF PRIORITY POLLUTANTS
APPLICABLE TO DYE MANUFACTURE AND USE:
DETO SURVEY OF PRIORITY POLLUTANTS
BELIEVED TO BE PRESENT IN COMMERCIAL DYES

(1) acrylonitrile
(2) anthracene
(3) arsenic
(4) benzidine
(5) bis (chloromethyl) ether
(6) cadmium
(7) chloroethane
(8) 2-chlorophenol
(9) chromium
(10) copper
(11) cyanide (inorganic)
(12) 3,3'-dichlorobenzidine
(13) 2,4-dichlorophenol
(14) 4,6-dinitro-o-cresol
(15) 2,4-dinitrophenol
(16) 2,4-dinitrotoluene
(17) 2,6-dinitrotoluene
(18) 1,2-diphenylhydrazine
(19) lead
(20) mercury
(21) methyl bromide
(22) methyl chloride
(23) napthalene
(24) nickel
(25) nitrobenzene
(26) 2-nitrophenol
(27) 4-nitrophenol
(28) N-nitrosodimethylamine
(29) N-nitrosodiphenylamine
(30) parachlorometa cresol
(31) PCB-1016
(32) PCB-1221
(33) PCB-1232
(34) PCB-1248
(35) PCB-1242
(36) PCB-1254
(37) PCB-1260
(38) phenol
(39) 2,4,6-trichlorophenol
(40) zinc

* * * * *

The Contribution of Dyes to the Metal Content of Textile Mill Effluents

ABSTRACT

Heavy metal ions in dyehouse effluent streams come from a variety of dyeing and dyeing-related operations as well as from some nondyeing operations. The primary objective of this paper is a realistic appraisal of the concentration of eight important metal ions in textile mill effluents which may be produced as a result of the presence of normally small amounts of metals in commercial dyes. This is done by correlating a tabulation of typical concentrations of each of these eight metals in each of the more important dye classes with several typical dyeing operations. A simple graphical method for relating metal concentrations in the dye, processing volumes of water per pound of fabric and metal concentrations in the effluent stream is presented.
The appraisal is extended to show that the same kind of evaluation can be made for the higher metal concentrations encountered in operations making deliberate use of metals such as in aftertreatments, oxidations or the use of metallized dyes.

KEY TERMS

Catalysts
Dyes
Metal Content of Dyes
Tramp Metals
Waste Treatment
Water Consumption

HEAVY metals find their way into textile mills in many ways. Virtually no product used in a mill is totally free of them. But this discussion is concerned only with the usually small amounts of tramp metal that get into dyes. Some are from the water in which the dye is prepared and some from raw materials—i.e., acids, alkalis, organic intermediates and materials of construction. Heavy metals are also sometimes used as catalysts in the synthesis of dyes and dye intermediates, and all traces of these catalysts are not always removed.

The study on which this report is based was concerned with eight metals: arsenic, cadmium, chromium, cobalt, copper, lead, mercury and zinc. They include those most likely to be present and some that are cited for special concern.

Table I is a composite of data from 1,298 dyes produced by eight manufacturers. It is doubtful that the results would be significantly different if a larger number of dyes from a greater number of manufacturers had been used. Limited data (*not shown*) indicate that the average metal content of nine fluorescent brightening agents and 18 solvent dyes is not greater than the average metal content of any other class tabulated. Similarly the data in Table I indicate that there are relatively few significant differences in the heavy metal content of the various dye classes. Except for the average chromium content of the vat dyes and the average zinc content of the basic dyes, the differences are less than ten-fold.

Most of the data presented in Table I have been obtained by X-ray fluorescence, emission spectrographic and atomic absorption techniques. Many of the arsenic measurements were made by the Gutzeit method, dithizone extraction was used to determine lead content at low levels, and in some cases colorimetric methods were used to provide improved sensitivity. Where emission spectrographic data are used and the metals are present in levels below the usual 10-20 ppm sensitivity of the technique, the result must be reported as "not detected." For numerical calculations the result must be considered as only less than the applicable sensitivity, not zero. The available data suggest strongly that the actual metal content frequently was well below the sensitivity of the measurement made. For this reason some of the metal concentrations presented in Table I are somewhat higher than the true value.

It must also be noted that there are infrequent but important exceptions to the average or typical heavy metal content reported in Table I. In many cases the realization that some dyes contain appreciably high metal content has prompted the manufacturers, where possible, to change their pro-

THIS REPORT WAS PREPARED BY the American Dye Manufacturers Institute, an organization comprised of most of the major U.S. dye manufacturers. The report was authored by William Allen of American Cyanamid Co., Eric Altherr of Sandoz Colors and Chemicals, Roderick H. Horning of the Dyes and Chemicals Division of Crompton & Knowles Corp., Joseph C. King of the Verona Division of Baychem Corp., John M. Murphy of ICI America Inc., William E. Newby of The Du Pont Co. and Max Saltzman of Allied Chemical Co. The report was presented at AATCC's 1972 national technical conference, held September 28-30 at Philadelphia, Pa., by its principal author, Roderick H. Horning.

cesses so as to reduce the amount of contaminant present in the dye or establish more stringent specifications for the intermediates used to prepare the dyes. The occurrences of these exceptional cases is significantly random and it would be misleading to try to generalize concerning which dyes have unusual amounts of which metals.

To avoid a possible misunderstanding it should be acknowledged that there are specific dyes in use that contain appreciable amounts of heavy metals as an integral part of the dye structure. Thus the so-called coppered dyes in the direct and fiber reactive dye classes contain copper complexed into the organic structure. Similarly the neutral premetallized dyes contain chromium or, less frequently, cobalt, as an integral part of the dye molecule. The metal content of the coppered and neutral premetallized dyes frequently runs in the vicinity of 3-4%. Because the metal is part of the dye, it exhausts onto the fiber with the dye during dyeing. Thus this metal is found in the effluent only to the extent that the dye is not exhausted from the bath. There are also a number of basic dyes in use that are prepared as a double salt containing zinc. The zinc content of these dyes is frequently in the range of 3% and is not exhausted with the dye.

Heavy Metals From Nondye Sources

Heavy metals are used intentionally for a wide variety of applications related to dyeing and finishing. Oxidations incident to some dyeing operations are conveniently performed with dichromates, and top chroming utilizes compounds of chromium. A variety of heavy metal compounds are used to improve washfastness or lightfastness on certain fabric/dye combinations. Many wash-wear, durable press and water repellent finishes require the use of heavy metal compounds as catalysts during their application. Aluminum and antimony compounds are used in some flame retardant finishes. Fibers and fabrics entering a mill sometimes contain appreciable quantities of heavy metals.

Again it should be noted that many of these metals become attached to the fabric, at least in part, and to this extent are not found in the mill effluent stream. The nature and concentration of effluent metals from nondye sources varies greatly from mill to mill. It is mentioned here only to avoid giving the impression that since most dyes do not appear to be serious offenders regarding metals in typical textile mill effluents that the mills have no problems with heavy metals. The dyer and finisher may wish to determine the metal content of all of the materials he is using so that he can gain a total perspective of his effluent problems if it is found that his waste contains metals at unacceptable levels.

This is an appropriate place to call attention to an error that seems to be perpetuating itself. Recent publications continue to refer to the prevalence of the cuprous ion method for dyeing acrylics although this method has been obsolete since the late 1950's.

Table I—Average Metal Concentration of Selected Dyes

Metal	Dye Class	Number of Dyes Analyzed	Average Metal Concentration (Parts Per Million)
Arsenic	Acid	415	< 1
	Basic	137	< 1
	Direct	313	< 1
	Disperse	177	< 1
	Fiber Reactive	46	1.4
	Vat	58	< 1
Cadmium	Acid	417	< 1
	Basic	137	< 1
	Direct	313	< 1
	Disperse	177	< 1
	Fiber Reactive	46	< 1
	Vat	58	< 1
Chromium	Acid	404	9
	Basic	137	2.5
	Direct	303	3.0
	Disperse	117	3.0
	Fiber Reactive	40	24
	Vat	59	83
Cobalt	Acid	300	3.2
	Basic	135	< 1
	Direct	271	< 1
	Disperse	154	< 1
	Fiber Reactive	46	< 1
	Vat	53	< 1
Copper	Acid	399	79
	Basic	136	33
	Direct	285	35
	Disperse	153	45
	Fiber Reactive	46	71
	Vat	59	110
Lead	Acid	408	37
	Basic	135	6
	Direct	315	25
	Disperse	161	37
	Fiber Reactive	46	52
	Vat	58	6
Mercury	Acid	460	< 1
	Basic	132	0.5
	Direct	350	0.5
	Disperse	196	< 1
	Fiber Reactive	46	0.5
	Vat	94	1.0
Zinc	Acid	421	< 13
	Basic	122	32
	Direct	311	8
	Disperse	166	3
	Fiber Reactive	46	4
	Vat	59	4

Table II—Typical Water Consumption for Common Dye Application Methods

Application Method	Gallons of Water Used Per Pound of Material
Continuous	20
Beck	28
Jet	24
Jig	12
Package	22

Water Consumption

The considerable quantity of wa generally used in the processing of te tiles greatly reduces the concentrati of waste products found in a mill's fluent. A number of recent referen (*1, 2, 3, 4*) indicate that water co sumption varies from several gallo per pound of fabric processed to abo 100 gallons per pound of fabric pr cessed. Experience suggests that t volume of effluent is commonly wi in the range of 10-35 gallons p pound of fabric.

The manner in which the fabric prepared and dyed is usually of mo significance regarding the volume water used than are the fabric and ber characteristics. For example, t volume of water per pound of fab used by a beck dyehouse will gen ally be about the same whether it pr cesses cotton or synthetics or wheth it runs suitings or carpets. Also, t various dye classes do not, of the

deto DYES ENVIRONMENTAL AND TOXICOLOGY ORGANIZATION, INC.
1075 CENTRAL PARK AVENUE, SCARSDALE, N.Y. 10583 • (914) 725-1492

November 8, 1978

An Addendum To DETO's "Report on Survey of 'Priority Pollutants' Believed to Be Present in Large Volume Commercial Dye Products"

I. Introduction

At a meeting on June 16, 1978, Dr. Gallup of the Environmental Protection Agency (EPA) and Dr. Buzell of Sverdrup, Parcel and Associates (EPA's contractor) requested the Dyes Environmental and Toxicology Organization, Inc. (DETO) to provide additional information about its "Report on Survey of 'Priority Pollutants' Believed to Be Present in Large Volume Commercial Dye Products" (Report).

In response to this request, DETO agreed to provide further explanations about: (1) the rationale for the selection of the 40 priority pollutants used in the survey; (2) the rationale for the selection of large volume commercial dyes with domestic sales exceeding 200,000 pounds per year used in the survey; and (3) the results with emphasis on the significance of individual priority pollutants found in these large volume commercial dyes. To provide these explanations, the DETO Ecology Committee (Committee) thoroughly re-evaluated the original responses to the survey and received answers to an additional question from all its member companies.

This addendum addresses the above items.

II. Purpose and Methodology of the Report and Survey

The Report and underlying survey were voluntarily prepared by DETO at the request of EPA. The purpose of the Report and survey was to assist EPA, given EPA's time constraints, in determining whether dyes in general are likely to be significant sources of priority pollutants that may be found in textile mill effluent. The Report was not intended to be a definitive sourcebook on the presence of priority pollutants in dyes utilizing time-consuming and expensive analytical testing. Rather it was intended to provide EPA with the best information available at the time of the survey without requiring analytical testing.

To accommodate this purpose and to facilitate a quick response necessary for EPA's short timetable, the Committee decided to limit the survey on a reasonable basis. As detailed below, the Committee utilized scientific and practical considerations in selecting only high volume commercial dyes and priority pollutants which were likely to be present in dyes for the survey. A questionnaire was sent to each DETO member company asking which of the listed priority pollutants were likely to be present in the listed dyes and whether the amounts present were believed to be greater than or less than 0.1%. The questionnaire also requested the member companies to report on other large volume commercial dyes not listed in the questionnaire.

III. Selection of the Priority Pollutants

From EPA's list of 129 priority pollutants, the Committee utilized its extensive expertise and experience in selecting those priority pollutants, a total of 40, which the Committee deemed likely to be present in dyes. The Committee used the following criteria in carefully reviewing each of EPA's priority pollutants and then eliminating from the list those which it believed were not likely to be present in or formed during the manufacturing process of dyes. When the Committee was in doubt, the pollutant was not eliminated.

A. Criteria for Selection

Process Considerations. The Committee considered each priority pollutant first with respect to its probable use as a raw material or an intermediate in the synthesis of dyes. It then considered each priority pollutant with respect to the likely process chemistry and unit operations including isolation steps such as precipitation, salting out, and filtration and washing of filter presscakes in which water-soluble unreacted raw materials are removed. The Committee judged that starting raw materials going through a series of chemical process steps or water-soluble intermediates are not likely to be present, even in trace quantities, in a finished dye. Thus the Committee eliminated those priority pollutants that are starting raw materials or reasonably water-soluble intermediates used in dyes.

Heavy Metals. The Committee noted that several metals are used in the manufacture of dyes. Some metals such as chromium and copper are used to form complexes with the organic molecule and become an integral part of dyes. Others such as zinc may be used to form suitable salts of dyes. Several are present primarily as tramp contaminants in trace quantities including arsenic, nickel, cadmium, lead and mercury. Thus the Committee selected these metals from the priority pollutant list for inclusion in the survey.

Solvents. Several priority pollutants are used in the manufacture of dyes as solvents for chemical reactions. After completion of reactions, these solvents generally are removed from the products by distillation, steam stripping and drying steps. The Committee believed that finished dyes were not likely to contain priority pollutants used as solvents, and therefore decided not to include such solvents in the survey questionnaire.

Polychlorinated Biphenyls (PCBs). Based on preliminary data available about the production of phthalocyanine organic pigments, the Committee decided that, under appropriate reaction conditions, PCBs conceivably could be generated in trace quantities during chemical processes using chlorinated benzenes as solvents. For this reason, PCBs were included in the questionnaire. The responding member companies, however, did not think the possibility of in-situ formation of PCBs was very likely and did not report any PCBs.

Adjuvants. During the formulation of commercial dyes, certain chemicals are added to impart desirable properties to the product. Among such chemicals are biocides and fungicides. The Committee selected those priority pollutants that were likely to be used as biocides.[1/]

B. Responses

The responses by the member companies indicate that the Committee used a very broad and widely inclusive approach in selecting the priority pollutants used in the survey. Of the 40 priority pollutants listed in the questionnaire, the member companies reported that only 18 of them were likely to be present. An additional seven priority pollutants not listed in the survey were reported so that the Committee received evaluations on a total of 25 priority pollutants thought

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1/ After preparation of the Report, it came to the attention of the Committee that certain alkyl phthalates, which are priority pollutants, are sometimes individually used in quantities of 1-2% as antidusting oils in dyes. These phthalates typically are octyl, di-n-butyl or diethyl phthalates. Because of inadequate information, this addendum and attached Table 1 do not analyze the significance of alkyl phthalates in large volume commercial dyes. It should be noted, however, that mineral oils, which are not priority pollutants, are more generally used as an anti-dusting oil than alkyl phthalates.

likely to be present in large volume commercial dyes.[1/] It should be reemphasized that none of the member companies reported that PCBs were likely to be present in large volume commercial dyes.

Of the seven additional priority pollutants listed, it was reported that: (1) toluene, ethylbenzene, monochlorobenzene, and 1,2, - dichlorobenzene are used as solvents; (2) acenaphthene and phenanthrene are starting raw materials; and (3) pentachlorophenol, which the Committee originally thought was no longer used in dye manufacturing, is added as a biocide adjuvant. As explained in Part V, the Committee does not believe that these additional priority pollutants in dyes are likely to be a significant source of such pollutants in textile mill effluent.[2/]

IV. Selection of Large Volume Commercial Dyes

To meet the time constraints imposed by EPA, the Committee selected only large volume commercial dyes,

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1/ The 40 priority pollutants listed in the survey and the additional seven priority pollutants reported are listed in Table 1. This table also includes the reported concentration ranges and comments about these priority pollutants with respect to large volume commercial dyes.

2/ See page 9.

a total of 70, defined as those dyes having domestic sales exceeding 200,000 pounds per year as reported by the International Trade Commission (ITC) in 1976. To insure completeness, the survey questionnaire also asked the member companies to include in their responses those commercial dyes upon which domestic sales exceeded 200,000 pounds but were not otherwise listed in the ITC report.[1/]

A. Responses

In addition to the 70 dyes listed in the questionnaire, the Committee received data from the member companies on an additional 81 dyes for a total evaluation of 151 products. In response to EPA's request for this addendum, the Committee also asked its member companies to determine how many of the products reported were distinct dyes. Because some of the additional products reported were generic in nature, 144 out of the 151 products evaluated were distinct dyes.

As stated in the original DETO report, the total sales volume of those dyes reported represents 55.3% of all domestic sales of dyes in 1976. Thus the survey covered a majority of dyes used in the United States.

V. Results and Discussion

In response to EPA's request for an additional explanation regarding the significance of priority pollutants

1/ The ITC does not compile statistics on all dyes because of confidentiality problems.

found in large volume commercial dyes, the Committee felt it would be helpful to determine the number of distinct dyes which contain each priority pollutant. To obtain this information, the Committee thoroughly re-evaluated the data submitted by the member companies.

This re-evaluation revealed that of the 144 dyes reported in the survey, 38 dyes were reported as not likely to contain any of the priority pollutants. The remaining 106 dyes were reported as likely to contain some priority pollutants. Only 31 of these dyes were reported as likely to contain any of the priority pollutants in amounts exceeding 0.1%.[1/] The priority pollutants contained in these dyes were restricted to three metals and three intentionally added biocides.

An analysis of the 106 dyes reported as likely to contain priority pollutants show that most of these dyes cannot be considered significant sources for priority pollutants found in textile mill effluent. Many of the priority pollutants likely to be present in these dyes were reported in trace amounts far below 0.1%. For example, while 40 dyes were thought likely to contain only metals as priority pollutants, many of these metals are tramp contaminants in amounts lower than 0.001%. Sixty of the 106 dyes were thought likely to contain organic priority pollutants not intentionally added as biocides and all in amounts of less than 0.1%.

1/ Table 2 contains a summary of the survey.

Of the six priority pollutants estimated to be present in concentrations exceeding 0.1%, chromium, copper and zinc are metals that are integral parts of those dyes in which they occur. Two of these metals, chromium and copper, are exhausted onto the fiber with the dye. The other three priority pollutants, p-chloro-m-cresol, pentachlorophenol and phenol, are phenolic chemicals intentionally added as bactericides and/or fungicides.[1/]

In responding to the original survey, DETO member companies selected 18 of the 40 priority pollutants listed as likely to be present in dyes and included an additional seven priority pollutants not listed. It should be noted that the seven additional priority pollutants reported are all intimately tied to a specific process chemistry or are added as adjuvants to the commercial products. Four of these pollutants, toluene, ethylbenzene, monochlorobenzene, and 1-2-dichlorobenzene, are solvents which the Committee judged as being completely removed during drying steps. Two others, acenaphthene and phenanthrene, are basic starting raw materials which the Committee concluded would not pass through the multiple chemical processes and unit operations required to produce a finished dye. The last one, pentachlorophenol, is added after preparation of the dye as a biocide adjuvant.

1/ After the preparation of the Report, it came to the attention of the Committee that certain alkyl phthalates may be present in concentrations exceeding 0.1%. See p.5 n.1.

VI. Conclusions

The DETO priority pollutant survey has succeeded in its stated objective. It has provided a guideline assessing the likely presence of dyes in priority pollutants that may be found in textile mill effluents. Given this objective and the time constraints imposed by EPA, DETO devised a valid questionnaire requiring a reasonable and conscientious response by its members to obtain the necessary data. Furthermore, DETO conscientiously responded to EPA's further request for additional information about the number of dyes containing priority pollutants.

As detailed in the original report and this addendum, the survey clearly demonstrates that, with the possible exceptions of chromium, copper, zinc, p-chloro-m-cresol, pentachlorophenol and phenol,[1/] large volume commercial dyes are not likely to be significant sources of priority pollutants in textile mill waters.

Respectfully submitted,

Stephen J. Kasprzak

Stephen J. Kasprzak
Executive Secretary

1/ Certain alkyl phthalates also may be possible exceptions. See p.5 n.1.

TABLE 1
EVALUATION OF PRIORITY POLLUTANTS
LIKELY TO BE PRESENT IN MAJOR DYES

		Number of Dyes Reported as Likely to Contain Priority Pollutants		
ority lutant ber	Substance	Less Than 0.1%	More Than 0.1%	Comments of DETO Screening Committee
1	acenaphthene	1	none	Reported in questionnai Possible early intermediate.
3	acrylonitrile	7	none	Can be used to make couplers.
5	benzidine	3	none	Used in manufacture of benzidine dyes, which are being rapidly phase out.
7	monochlorobenzene	1	none	Reported in questionnai May be used as process solvent.
16	chloroethane	none	none	Can be used as ethylati agent.
17	bis (chloromethyl) ether	none	none	Do not believe present; if so, as unintentional by-product or for chloroethylation (being phased out).
21	2,4,6-trichlorophenol	none	none	May be present as bacteriostat/fungicide.
22	parachlorometacresol	none	7	Possible intermediate. Also may be used as biocide.
24	2-chlorophenol	none	none	Possible intermediate.
25	1,2-dichlorobenzene	1	none	Reported in questionnai May be used as process solvent.
28	3,3-dichlorobenzidine	none	none	Possible intermediate.
31	2,4-dichlorophenol	none	none	Possible intermediate.
35	2,4-dinitrotoluene	none	none	Possible early intermediate.
36	2,6-dinitrotoluene	none	none	Possible early intermediate.

TABLE 1
EVALUATION OF PRIORITY POLLUTANTS
LIKELY TO BE PRESENT IN MAJOR DYES

Priority Pollutant Number	Substance	Number of Dyes Reported as Likely to Contain Priority Pollutants: Less Than 0.1%	More Than 0.1%	Comments of DETO Screening Comments
77	anthracene	1	none	Possible very earl[illegible] intermediate.
80	phenanthrene	2	none	Reported in questi[illegible] Possible very earl[illegible] intermediate.
86	toluene	25	none	Reported in questi[illegible] May be used as sol[illegible]
106	PCB-1242	none	none	Unlikely to be pre[illegible] but may be formed trace by-product.
107	PCB-1254	none	none	Unlikely to be pre[illegible] but may be formed trace by-product.
110	arsenic	1	none	May be present as impurity.
113	cadmium	3	none	May be present as impurity.
114	chromium	29	6	May be a part of [illegible] structure.
115	copper	38	10	May be a part of [illegible] structure.
116	cyanide (inorganic)	none	none	May be present as impurity.
117	lead	28	none	May be present as impurity.
118	mercury	39	none	May be present as impurity.
119	nickel	26	none	May be present as impurity.
123	zinc	27	4	May be a part of
125-129	additional PCB's	none	none	Unlikely to be p[illegible] but may be forme[illegible] trace by-product

TABLE 1
EVALUATION OF PRIORITY POLLUTANTS
LIKELY TO BE PRESENT IN MAJOR DYES

rity utant ber	Substance	Number of Dyes Reported as Likely to Contain Priority Pollutants: Less Than 0.1%	More Than 0.1%	Comments of DETO Screening Committee
	1,2-diphenylhydrazine	none	none	Possible early intermediate in benzidine dy which are being rapidly phased out.
	ethylbenzene	25	none	Reported in questionnaire May be used as solvent.
	methyl chloride	none	none	Can be used as methylating agent.
	methyl bromide	5	none	Can be used as methylating agent.
	naphthalene	2	none	Possible very early intermediate.
	nitrobenzene	none	none	Possible very early inmediate or solvent.
	2-nitrophenol	none	none	Possible very early intermediate.
	4-nitrophenol	4	none	Possible very early intermediate.
	2,4-dinitrophenol	2	none	Possible intermediate.
	4,6-dinitro-o-cresol	none	none	Possible intermediate.
	N-nitrosodimethylamine	1	none	Do not believe present; if so, only as unintentional by-product.
	N-nitrosodiphenylamine	none	none	Do not believe present; if so, only as unintentional by-product.
	pentachlorophenol	2	6	Reported in questionnaire May be used as biocide.
	phenol	20	1	Possible intermediate, process solvent, or biocide.

TABLE 2
SUMMARY OF RESULTS
DETO PRIORITY POLLUTANT SURVEY

TOTAL number of different major dyes reported: 144

TOTAL number of different major dyes reporting priority pollutants: 106

TOTAL number of different major dyes reporting priority pollutants 0.1%: 31

TOTAL number of different major dyes reporting only metals: 40

TOTAL number of additional different major dyes reporting both metals and phenolic bacteriostats as only priority pollutants: 6

TOTAL number of different major dyes reporting organic (non-bacteriostat) priority pollutants (all less than 0.1%): 60

(6) Priority Pollutants 0.1%: Chromium
Copper
Zinc
p-Chloro-m-cresol
Pentachlorophenol
Phenol

After preparation of the Report, some DETO members reported that certain alkyl phthalates were possible priority pollutants in amounts exceeding 0.1%. See p. 5 n.1

(19) Additional Priority Pollutants (Many trace quantities about 0.001%):

Acrylonitrile	Nickel
Anthracene	4-Nitrophenol
Arsenic	N-Nitrosodimethylamine
Benzidine	Toluene
Cadmium	Ethylbenzene
2,4-Dinitrophenol	Acenaphthene
Lead	Monochlorobenzene
Mercury	1,2-Dichlorobenzene
Methyl bromide	Phenanthrene
Naphthalene	

APPENDIX F

DESCRIPTIONS OF EPA/INDUSTRY FIELD STUDY MILLS

MILL A

MILL B

MILL D

MILL DD

MILL E

MILL F

MILL O

MILL P

MILL Q

MILL S

MILL V

MILL W

MILL Y

MILL A

Mill A is a Subcategory 1 Wool Scouring facility that performs raw grease wool scouring. Reported average production is 23,600 kg/day (52,000 lb/day). The processing results in a water usage of 10.0 l/kg (1.2 gal/lb) and a wastewater discharge of 1,380 cu m/day (364,000 gal/day).

Wastewater treatment at Mill A consists of primary sedimentation (grit removal), biological aeration (1 basin with a total volume of 1.5 mgd), secondary clarification scum removal, and disinfection (chlorine). Aeration detention time is approximately 72 hours, and air is provided by surface aerators at a power-to-volume ratio of 160 hp/mil gal.

MILL B

Mill B is a Subcategory 2 Wool Finishing mill that is involved in manufacturing and finishing wool and blended wool fabrics. The primary fibers finished are wool and cotton. An important feature of this mill it that a large percentage of the wool used is from recycled woolen goods. The principal manufacturing operations are scouring and both stock and fabric dyeing. Production during the field studies averaged 30,380 kg/day (approximately 67,000 lb/day) with a water usage of 122 l/kg (14.6 gal/lb) and an average wastewater discharge of 3,700 cu m/day (0.98 mgd) (less than 1 percent sanitary waste).

Wastewater treatment at Mill B consists of fine screening (vibratory), equalization (mixed), biological aeration (total volume under aeration of 1.2 mil gal), secondary clarification, and disinfection (chlorine). Aeration basin detention time is approximately 24 hours, and air is provided by surface aerators at a power-to-volume ratio of 133 hp/mil gal. However, this treatment fails to meet BPT guideline limitations for BOD_5. Although more than 99 percent of the flow treated at this plant is process wastewater from the mill, it is technically a POTW since the system is run by the municipality in which the mill is located.

MILL D

Mill D is a Subcategory 4c Woven Fabric Finishing mill that performs desizing (PVA), bleaching, dyeing, and functional finishing. During the field studies, the production averaged 31,900 kg/day (approximately 70,300 lb/day) and included fabrics of 100 percent cotton, cotton/polyester blends, cotton/rayon blends, and 100 percent polyester. The processing resulted in an average water usage of 48.4 l/kg (approximately 5.8 gal/lb) and a wastewater discharge of 1,550 cu m/day (0.41 mgd), a very small portion of which was sanitary waste.

Wastewater treatment at Mill D consists of coarse screening, neutralization (addition of acid), fine screening, aeration (two basins in series with a total volume of 2.4 mil gal), secondary clarification, and disinfection (chlorine). Aeration detention time is approximately 48 hours, and oxygen is provided by surface aerators at a power-to-volume ratio of 125 hp/mil gal.

MILL DD

Mill DD is actually two facilities that share a common wastewater treatment plant. One facility is a Subcategory 4c Woven Fabric Finishing mill that performs desizing (starch) scouring, bleaching, mercerizing, dyeing (continuous), and functional finishing. The other facility includes a Subcategory 3 Low Water Use Processing mill and a Subcategory 7 Stock & Yarn Finishing mill that perform weaving and package dyeing of yarns, respectively. During the field studies, 63,500 kg/day (approximately 140,000 lb/day) of 100 percent cotton (17 percent), cotton/polyester blends (79 percent), and cotton/polyester/nylon blends (4 percent) were being finished by the two facility complex. Approximately 26 percent of the fabric is woven with yarn that is package dyed. The processing resulted in an average water usage of 250 l/kg (approximately 30 gal/lb) and an average wastewater discharge of 20,400 cu m/day (5.4 mgd).

Wastewater treatment at Mill DD consists of coarse screening, neutralization (addition of acid), aeration (one basin with a total volume of 12 mil gal), secondary clarification, and disinfection (chlorine). Aeration detention time is approximately 48 hours and air is provided by surface aerators at a power-to-volume ratio of 87.5 hp/mil gal.

MILL E

Mill E is a Subcategory 5a Knit Fabric Finishing mill that performs scouring, dyeing, and functional finishing (crease-resistant, water-repellent, and flame-resistant chemicals). Production is approximately 19,000 kg/day (42,000 lb/day) of nylon apparel fabric and 680 kg/day (1,500 lb/day) of Nomex fabric. The processing results in a water usage of 133 l/kg (16 gal/lb) and a wastewater discharge of 2,650 cu m/day (0.70 mgd).

Wastewater treatment at Mill E consists of coarse screening, aeration (one basin with a total volume of 3.7 mil gal), secondary clarification, and disinfection (chlorine). Aeration detention time is approximately 48 hours, and air is provided by surface aerators at a power-to-volume ratio of 240 hp/mil gal.

MILL F

Mill F is a Subcategory 6 Carpet Finishing facility that is engaged in dyeing tufted carpet made from polyester and nylon yarn. Production during the field studies was reported to average 113,375 kg/day (250,000 lb/day). The processing results in an average water usage of 46.7 l/kg (5.6 gal/lb) and an average wastewater discharge of 5,300 cu m/day (1.4 mgd).

Wastewater treatment at Mill F consists of aeration (one basin with a total volume of 10 mil gal), secondary clarification, effluent polishing (one 18 mil gal tertiary lagoon), and disinfection (chlorine). Aeration detention time is approximately 190 hours, and air is provided by surface aerators at a power-to-volume ratio of 40 hp/mil gal.

MILL O

Mill O is a Subcategory 2 Wool Finishing mill that converts wool and nylon fiber into finished apparel and upholstery fabrics. Occasionally, woolen blankets are manufactured. The processing includes spinning, weaving, stock dyeing, piece dyeing, carbonizing, fulling, and functional finishing. Average production is reported to be 7,700 kg/day (17,000 lb/day) and wastewater discharge averages 3,785 cu m/day (1 mgd). The mill has an average water usage of 475 l/kg (57 gal/lb).

Wastewater treatment at Mill O consists of neutralization (alkali feed), fine screening (vibratory), biological aeration (1 basin with a total volume of 1.5 mil gal), and secondary clarification. Phosphoric acid is added as nutrient. Aeration detention time is approximately 36 hours, and air is provided by surface aerators at a power-to-volume ratio of 66 hp/mil gal.

MILL P

Mill P is an integrated facility that includes a Subcategory 4c Woven Fabric Finishing mill and a Subcategory 7 Stock & Yarn Finishing mill. Woven fabric finishing operations consist of desizing (PVA, starch), scouring (caustic), bleaching (peroxide and chlorine), mercerizing (caustic recovery practiced), dyeing, and functional finishing. Yarn is dyed for the manufacture of denim fabric. During the field studies, the production of woven fabric averaged approximately 77,000 kg/day (170,000 lb/day); yarn dyeing is generally less than 8 percent of the total production. Production included sheeting, denim, shirting, and broadcloth of 100 percent cotton and cotton/polyester blends. The processing resulted in an average water usage of 100 l/kg (11.9 gal/lb) and a wastewater discharge of 7,570 cu m/day (2.0 mgd); approximately 7.5 percent of which was sanitary waste.

Wastewater treatment at Mill P consists of coarse screening, neutralization (addition of acid), equalization, aeration (two parallel basins with a total volume of 14 mil gal), secondary clarification, and disinfection (chlorine). Aeration detention time is approximately 72 hours and air is provided by surface aerators at a power-to-volume ratio of 57 hp/mil gal.

MILL Q

Mill Q is actually two Subcategory 5 Knit Fabric Finishing mills that discharge to a common treatment plant. During the field studies, the production of knit fabric averaged approximately 72,560 kg/day (160,000 lb/ day). Production included fabrics of 100 percent polyamide, 100 percent polyester, 100 percent acetate, 80 percent acetate/20 percent nylon, 95 percent polyester/5 percent nylon, and 80 percent triacetate/20 percent nylon. The processing resulted in an overall water usage of 130 l/kg (15.6 gal/lb) and a wastewater discharge of 9,460 cu m/day (2.5 mgd), approximately one percent of which was sanitary waste.

Wastewater treatment at Mill Q consists of coarse screening (bar and basket), equalization (aerated), aeration (two 3.2 mil gal basins), secondary clarification, disinfection (chlorine), multi-media filtration (3.5 gpm/ft^2 design with precoagulant and/or activated carbon injected into the filter influent), and post aeration. Aeration detention time is approximately 15 hours, and air is provided by surface aerators at a power-to-volume ratio of 148 hp/mil gal.

MILL S

Mill S is a Subcategory 7 Stock & Yarn Finishing facility that dyes and finishes industrial sewing thread and hand knitting yarn. Processing includes bleaching, mercerizing, package dyeing, and functional finishing. Average daily production is reported as 32,200 kg/day (71,000 lb/day). The processing results is an average water usage of 161 l/kg (19.3 gal/lb) and an average wastewater discharge of 5,300 cu m/day (1.4 mgd).

Wastewater treatment at Mill S consists of equalization (mixed), aeration (one basin with a total volume of 3.9 mil gal), secondary clarification, effluent polishing (one 3.8 mil gal tertiary lagoon), disinfection (chlorine), and post aeration. Aeration basin detention time is approximately 62 hours, and air is provided by surface aerators at a power-to-volume ratio of 46 hp/mil gal.

MILL V

Mill V is a Subcategory 4c Woven Fabric Finishing mill that performs desizing (PVA, CMC, and starch), scouring, bleaching, mercerizing, dyeing (continuous), and functional finishing (mildew, soil & water repellents, and hand improvers). During the field studies, the production averaged approximately 95,200 kg/day (210,000 lb/day) and included fabrics of 65 percent polyester/35 percent cotton (approximately 56 percent), 50 percent polyester/50 percent cotton (approximately 26 percent), 20 percent polyester/80 percent cotton (approximately 7 percent), 18 percent polyester/82 percent cotton (approximately 9 percent), and 15 percent polyester/85 percent cotton (approximately 2 percent). The processing resulted in an average water usage of 122 l/kg (14.6 gal/lb) and a wastewater discharge of 11,350 cu m/day (approximately 3.0 mgd); less than one percent of the flow is sanitary waste.

Wastewater treatment at Mill V consists of coarse screening, neutralization (addition of acid), aeration (2 basins operated in series with a total volume of 10 mil gal), secondary clarification, and disinfection (chlorine). Aeration detention time is approximately 60 hours, and air is provided by surface aerators at a power-to-volume ratio of 41 hp/mil gal.

MILL W

Mill W is a Subcategory 5b Knit Fabric Finishing mill that performs knitting, bleaching, scouring, dyeing, printing, and functional finishing. The primary fibers utilized are cotton, polyester, SEF, Kohjin, and nylon. SEF and Kohjin are special flame retardant fibers. During the field studies, production averaged 23,600 kg/day (approximately 52,000 lb/day) and included fabrics of 100 percent cotton, 100 percent polyester, 100 percent Kohjin, 65 percent SEF/35 percent polyester, and 82 percent Kohjin/18 percent nylon. The processing resulted in an average water usage of 152 l/kg (18.2 gal/lb) and an average wastewater discharge of 3,570 cu m/day (0.94 mgd).

Wastewater from the printing operation passes through an air flotation tank that at the time of sampling was being used as a gravity separator. It then combines with the wastewater from the bleaching and dyeing operations for complete biological treatment. As an alternate route, the wastewater from the air flotation tank can go to a distillation column for solvent recovery. This mode of treatment was not in use at the time of the sampling. Treatment of the combined waste stream consists of coarse screening, equalization (nitrogen added as a nutrient), fine screening (not in service at time of sampling) biological aeration (one basin with a total volume of 2.7 mil gal), secondary clarification, and disinfection (chlorine). Aeration detention time is approximately 72 hours, and air is provided by surface aerators at a power-to-volume ratio of 37 hp/mil gal.

MILL Y

Mill Y is a Subcategory 4c Woven Fabric Finishing facility that performs desizing, scouring, bleaching, mercerizing, functional finishing, and both yarn and fabric dyeing. The processing results in an average water usage of 182 l/kg (21.8 gal/lb), and an average discharge of 7,950 cu m/day (2.1 mgd).

Wastewater treatment at Mill Y consists of equalization (mixed with 26 hp/mil gal), neutralization (acid addition) coarse screening, aeration (two basins with a total volume of 10.5 mil gal), coagulation (polymer addition before secondary clarification), and secondary clarification. Aeration basin detention time is approximately 120 hours, and air is provided by surface aerators at a power-to-volume ratio of approximately 58 hp/mil gal.

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