The Cost of Clean Water

U.S. DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration

VOLUME III

INDUSTRIAL WASTE PROFILE NO. 4
TEXTILE MILL PRODUCTS

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THE COST OF

CLEAN WATER

Volume III

Industrial Waste Profiles
No. 4 - Textile Mill Products

U. S. Department of the Interior
Federal Water Pollution Control Administration

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PREFACE

The Industrial Waste Profiles are part of the National Requirements and Cost Estimate Study required by the Federal Water Pollution Control Act as amended. The Act requires a comprehensive analysis of the requirement and costs of treating municipal and industrial wastes and other effluents to attain prescribed water quality standards.

The Industrial Waste Profiles were established to describe the source and quantity of pollutants produced by each of the ten industries studied. The profiles were designed to provide industry and government with information on the costs and alternatives involved in dealing effectively with the industrial water pollution problem. They include descriptions of the costs and effectiveness of alternative methods of reducing liquid wastes by changing processing methods, by intensifying use of various treatment methods, and by increasing utilization of wastes in by-products or water reuse in processing. They also describe past and projected changes in processing and treatment methods.

The information provided by the profiles cannot possibly reflect the cost or wasteload situation for a given plant. However, it is hoped that the profiles, by providing a generalized framework for analyzing individual plant situations, will stimulate industry's efforts to find more efficient ways to reduce wastes than are generally practiced today.

James M. Quigley
Commissioner
Federal Water Pollution Control Administration

INDUSTRIAL WASTE PROFILE

TEXTILE MILL PRODUCTS

Prepared for F.W.P.C.A.

FWPCA Contract Number 14-12-101
June 30, 1967

Federal Water Pollution Control Administration
September 1967

SCOPE

The scope of material included in this profile report conforms to the requirements of the United States Department of the Interior Federal Water Pollution Control Administration Contract Number 14-12-101. Within the available 90 day study period, engineering and economic data has been critically studied by means of a total industry approach. The relationship of the product to the alternative sub-system manufacturing processes has been reviewed in the field and office with responsible industry representatives. The cognizent professional associations, and industrial experts have presented their data and viewpoint, and have reviewed our draft information. Key plant managers have cooperated in allowing limited spot checks of their plant sub-processes and waste sampling. The literature has, of course, been completely reviewed.

Because of the wide diversity of plants and processes, we have attempted to achieve a comprehensive overview of the approximate subprocesses. We have evaluated the total relationship of products produced, waste pollution load, economics involved, and long term environmental quality factors.

INDUSTRIAL WASTE PROFILE

TEXTILE MILL PRODUCTS

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SUMMARY TEXTILE MILL PRODUCTS

The textile industry as a whole is a major factor in the American economy. Approximately 900,000 people are employed in over 7000 plants. According to the 1966 Statistical Abstract of the United States, the industry has an invested capital of over $10 billion, and spent over $1 billion on new plants and equipment in 1966.

This Industrial Waste Profile is divided into three major sections. The first section surveys the Wool Textile Weaving and Finishing Industry; the second section, the Cotton textile Finishing Industry; and the third section, the Synthetic textile Finishing Industry. All of these industries are complex, variable, and in constant transition. As research and development provide new chemicals, processes, machinery, and techniques, and as consumer demand for types of fabric and color varies, the wastes generated by the industry change also. For this reason, the study has emphasized the principal types of textiles produced. Many less common products such as linen, olefins, etc. have not been specifically described.

For the purposes of this study, it is important to differentiate between the finishing process and the textile operations preceding it. Except for the scouring of raw wool, the making of raw fiber into unfinished cloth or yarn is essentially a dry operation. The finishing operation is a large producer of liquid wastes, however, and is the segment of the industry which concerns us.

Cotton fiber is the single most popular and important fiber in the American textile industry. Its excellent absorptive and user characteristics, as well as reasonable price, contribute to its stable market of about 7-9 million bales per year consumed during the past decade; this quantity represents approximately one-half of the total fiber used by our textile industry. The wool and rayon market is also reasonably stable, approximating 10 and 16 percent respectively of the total decade's fiber consumption. Non-cellulosic synthetic fibers have markedly increased their annual domestic consumption from approximately 3 million bales equivalent in 1957 to some 6 million bales equivalent in 1966. Natural fiber mixtures in blend with synthetics are becoming increasingly popular because of cost, appearance and utility.

As a general rule, there are four basic subprocesses involved in the finishing of textiles. These can be classified as follows:

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1. Scouring
2. Dyeing and/or Printing
3. Bleaching
4. Special Finishing

Special finishing (4) is meant to include all subprocesses which cannot be classified in one of the preceding three categories.

Cotton and synthetic fibers are generally woven into cloth before any finishing operations are applied. Wool is generally washed (scoured) and dyed before being woven into cloth. In either case, weaving contributes indirectly to the wasteload by the addition of sizes, and anti-static lubricants which may be required to facilitate handling and use of the fiber or fiber blend.

Desizing and scouring of natural fibers - cotton and wool - removes natives impurities such as dirt and grease as well as the chemical additives mentioned above. In the wool industry, scouring removes impurities approximately equal in weight to the residual fiber weight, creating one of the strongest liquid wastes in terms of BOD, of any industry. Synthetic fiber scouring wastes, on the other hand, are relatively low in both pollution and volume due to the lack of natural impurities and the small amounts of additives used. The cotton finishing industry also commonly desizes woven cloth for starch removal followed by a thorough scouring, for the removal of impurities.

In both the cotton and wool industries, scouring and washing is the major source of pollution, contributing 50 to 75 percent of the total plant BOD and solids. In the synthetic textile industry, scouring and washing is not a major contributor to the wastestream, generally producing less than half of the total plant pollution measured as BOD.

The types of dyes employed by the textile industry include direct, acid, fiber reactive, vat, basic, naphthol, sulphur, and acetate. Usage depends on the characteristics of the fiber, the color, and the desired finish. Some synthetic textiles require the use of special carriers to achieve satisfactory penetration of the dye into the fiber. These carriers are very highly polluting and present a major source of pollution in the finishing of these synthetic fibers. In some cases, pressure dyeing at high temperatures is an alternative method to the use of carriers in dyeing. This method avoids both the cost and pollution of carrier dyeing while allowing satisfactory dye penetration in a shorter period of time.

Printing is almost invariably done by roller application of various dye pastes. Chemical treatment follows to fix the color, and a final wash and rinse removes any residue. Printing process waste pollution is usually not high.

The pollution load from the dyeing and printing subprocesses is approximately 3 to 10 percent of total plant BOD and solids in the wool industry. In cotton finishing the range is 15 to 35 percent, and for synthetics it is 5 to 80 percent. Acids, salts, and organic dyes of many types are employed and then wasted to the sewer after each dye cycle.

Bleaching is generally accomplished by soaking the cloth in a standing bath containing an oxidizing agent in solution, or in a continuous bleaching process. Nearly all of the cotton produced is bleached regardless of its final color using hypochlorite or hydrogen peroxide. Wool is commonly bleached with hydrogen peroxide, and acid. Synthetics are bleached with hydrogen peroxide, sodium chlorite, peracetic acid, sodium chloride, or other chemicals.

Only a small percentage of wool and synthetic cloth production is bleached white. Natural wool is yellow in color and bleaching is required only when white or light colors are desired. Synthetic cloth is bleached for the removal of stains or when a translucent bluish-white color is desired.

Bleach wastes may be toxic and acidic but are not high in pollutant concentration and generally do not contribute more than 5 percent of the plant's organic wasteload.

Special finishes include waterproofing, moth-proofing, fire-proofing, pre-shrinking, brightening, anti-wrinkling, etc. In addition, wool is fulled to achieve a felt-like appearance and cotton may be mercerized or causticized to smooth its surface. Most of these special finishing processes involve chemical treatment and removal of residue by washing and/or rinsing.

The pollution contribution of special finishing subprocesses is in the range of 5 to 15 percent of the plant total.

It is evident that the wasteloads from each basic subprocess vary over a wide range of values due to the large number of different fibers produced, each having its own distinctive characteristics. However, variations also exist between different plants processing the same fiber, due to technological differences in production procedures and many other variables which may exist. Additionally, many of the nation's textile mills are involved in the production of cloth composed of a combination of fibers requiring a variable process methodology dependent on cloth composition.

Although quantities may vary, the wasteload characteristics are generally similar for all textile mills processing the same fiber.

Wool wastes are characterized by high BOD, high solids concentration, and high grease content. Dye wastes contain color which is extremely difficult to remove by common waste treatment methods. Wool grease presents an especially difficult problem in that pre-treatment for removal may be necessary before efficient biological treatment of the plant effluent is feasible. The cost of grease removal is generally higher than the market value of recovered wool grease.

Cotton finishing wastes are not nearly as strong as those produced by the wool industry, having no grease and a relatively low solids content. Other characteristics are high BOD (although considerably lower than that found in wool wastes) and possible high color content. The average pollutant quantities produced per 1000 lb of finished cotton are 155 lb BOD, 70 lb suspended solids, and 205 lb total dissolved solids. Cotton finishing wastes can be treated by common biological methods and do not present any special problems.

Synthetic finishing wastes are generally lower than cotton finishing wastes in pollutant quantities and characteristics. One significant difference can be the toxicity of synthetic dye wastes when metallic ion content carriers are used. Pollutant quantities per 1000 lb of finished cloth vary over a wide range of values due to the many different types of fibers processed. The ranges are 20 to 250 lb BOD, 20 to 160 lb suspended solids, and 20 to 600 lb total dissolved solids. A breakdown of these quantities by type of fiber is given in the text.

Toxicity of synthetic fiber dye wastes can retard or prevent biological waste treatment when concentrations are significant. In such cases chemical pre-treatment will be required prior to biological treatment or discharge to municipal sewers.

Water usage in the textile industries is relatively high due to the large amounts of water required in washing and rinsing operations. Cotton and wool finishing mills use 30,000 to 70,000 gal of water per 1000 lb of cloth. Synthetic finishing mills use considerably less water, ranging from 3000 to 29,000 gal/1000 lb cloth This lower water requirement reflects the lack of natural impurities on synthetic fibers, allowing less thorough washing as compared to cotton or wool. Water reuse has not been practiced to a great extent, however, it is expected that greater recirculation practices will be adopted in the future as water costs and pressures from regulatory agencies increase.

The wastes from a textile mill come from two major sources: (1) the natural impurities in the fiber such as dirt, grease, vegetable matter, etc. and (2) the process chemicals used such as detergents, dyes, sizes, oils, anti-stats, and lubricants. Significant reductions in pollution have been achieved by the substitution of low BOD chemicals for higher BOD chemicals. For example, the substitution of synthetic detergents for soap in wool scouring may decrease the BOD load by 25 percent. The use of continuous rather than batch type manufacturing subprocesses has been found to reduce both chemical and water requirements, reducing BOD loads by as much as 20 percent. Some of the natural impurities can be recovered from the waste and disposed as a solid waste or sold, as in the case of wool grease. In general, reductions in waste generated may result from substitution of process chemicals, more efficient machinery, better process control and instrumentation, more efficient housekeeping and recovery and reuse of chemicals.

When possible, industrial waste treatment methods currently employ low cost processes developed for domestic sanitary sewage. Additionally, screening and equalizing basins are used for pretreatment.

Textile finishing plant effluents contain waste materials similar to the constituents of domestic sewage and can be effectively treated to any degree desired within the constraints of process technology and related treatment facility expenditures.

Segregation of types and concentrations of industrial wastes and recycling of process fluids can reduce total water consumed and solids generated. Pre-treatment of industrial wastes containing chemical constituents that are complex, or not readily bio-degradable, or are odorous, highly acidic, basic, or otherwise toxic may require special additional costly pre-treatment plants. Chemical-mechanical facilities involving such processes as precipitation, flotation, scrubbers, neutralization tank, and other processes can be used to produce an effluent with more acceptable bio-degradable characteristics. The conversion of wastes into a useful resource, or alternatively, the modification of the waste producing subprocess to reduce waste, is a generally desirable goal.

Screening is usually used to remove fibers which may hinder subsequent treatment operations. Equalization and holding is generally necessary due to batch dumping of many of the process wastes, which would otherwise create shock loads and intermittent flows through the treatment system.

The percentage of textile wastes treated by municipal plants is also increasing steadily with urbanization of formerly rural areas and construction of new plants in established communities.

Generally capital costs of manufacturing have increased greatly since 1950, however, operating and maintenance costs have decreased slightly allowing overall production costs to remain fairly stable. The stability in production costs can be attributed to the trend toward automation, thus avoiding the rising costs of labor.

The total number of employees on textile mill payrolls has decreased approximately 30 percent from 1950 to 1963. In this same time period, production has increased approximately 22 percent. A large portion of this increase can be attributed to synthetic textiles since cotton and wool production has not increased to a great extent. Total production per employee has increased approximately 57 percent in the time period of 1950 to 1963.

Costs of treatment in the textile industries are a small fraction of the costs of production. The percentage of waste treatment cost in total production cost is estimated at 2.0 percent for wool, 1.7 percent for cotton, and 2.2 percent for synthetic textiles. These percentages are for the entire industry. The main body of the text covers costs throughly in section IV of each textile study.

The cotton finishing industry is the largest producer of wastes in the textile finishing field. It is estimated that the net pollution reaching the nation's watercourses from cotton finishing operations will be 270 million lb of BOD in 1967. The contribution of the wool industry is estimated at 130 million lb and that of the synthetic textile industry 106 million lb of BOD in 1967. These estimates represent the difference between the waste generated and the waste removed by industrial and municipal waste treatment plants.

By concurrently projecting the growth of the industries and the rate of adoption of waste treatment practices, a projection ot net waste quantities can be derived. In the cotton industry, the net waste discharged is expected to decrease steadily to half of the 1963 quantity in 1977. Net wool wastes discharged are also expected to decrease steadily to 75 percent of its 1963 value in 1977. Due to the tremendous growth rate of the synthetic textile industry, the net waste discharged is expected to increase, reaching a peak in 1968, then decrease gradually returning to its 1963 level in 1977. (A year by year breakdown of the above discussion can be found in table form in the text.) The anticipated decrease is net pollution reaching the nation's watercourses from the textile finishing industry is based on the assumption that more efficient manufacturing processes will be utilized, a larger percentage of the waste will be treated, waste treatment facilities will achieve more efficient pollution removal, increased pressure by regulatory agencies on all levels, and the expected rapid increase in use of synthetic fibers.

Industrial Waste Profile

Wool Textile Weaving
and Finishing - SIC 2231

U. S. Department of the Interior
Federal Water Pollution Control Administration
I.W.P. No. 4 - Wool Textile Weaving and Finishing

INDUSTRIAL WASTE PROFILE STUDIES
TEXTILE INDUSTRY

SIC 2231, WOOL INDUSTRY

INTRODUCTION

Wool fiber is probably the most ancient and valuable cloth fiber used by man. The American wool market is reasonably stable and approximates about 400 million clean lb or roughly 10 percent of the total fibers consumed annually by our textile industry. Fine wool suiting, rugs, blankets, sweaters, and other products are renowned for both their beauty and utility. Wool mixtures in blend with synthetics and even cotton are becoming increasingly popular because of their reduced cost, improved weight, washability, and wear, and other characteristics. The influence of recent synthetics competition has assisted in stimulating some technological advancement into the wool processing industry. There appears to be a trend toward larger plants to replace older, less efficient operators. About 200 million clean lb of fiber and 125 million lb of rugs are imported annually into the United States. Since raw wool fiber finishing produces particularly strong waste pollution, by-product reclamation and effective treatment control measures are needed.

INDUSTRIAL WASTE PROFILE STUDIES
TEXTILE INDUSTRY

SIC 2231, WOOL INDUSTRY

I. PROCESSES AND WASTES

A. Fundamental Processes

Raw sheep wool receives a preliminary wash and rinse. Then, the fairly clean wool is carbonized with acid and heating to remove the residual waste. After another washing, the fibers are ready for carding, fulling and weaving. They can be dyed either before or after weaving.

The fundamental processes in the production of finished wool are scouring, dyeing, carding, fulling, washing, carbonizing, and bleaching. Although fulling discharges little direct waste, it contributes to the total wasteload by the addition of biodegradable chemicals which are removed in the washing process. Except for carding, all of the remaining processes are direct sources of waste.

The following brief description of processes is a generalized summary based on industry practices over the past 20 years.

1. Scouring: Scouring is carried out in a series of 2 to 6 bowls of 1500 to 3000 gal capacity each (known as a scouring train). A 4-bowl train is the type most commonly used for an average typical plant. The first 2 bowls are filled with a detergent solution generally composed of soap or synthetic detergent (often non-ionic), alkali, and water. The third bowl is a standing rinse and the last may be either a standing or overflowing rinse. In many plants, a counterflow arrangement may be used where the relatively cleaner waters at the end of the train flow backward for reuse in the preceding bowls.

The temperature is usually maintained between 115° and 125°F although temperatures as high as 150°F have been used, especially with synthetic detergents. Mechanical rakes advance the wool through the bowls continuously, passing it through squeeze rollers between bowls to remove most of the dirty scouring solution before admitting it to the cleaner bath.

Many mills find it more economical to have their wool degreased by commission houses using the aforementioned processes.

Scouring emulsifies the dirt and grease and produces a brown, thickly turbid waste which is often covered with a greasy scum and contains considerable settleable mineral matter. It is strongly alkaline and very putrescible.

The bowls are generally dumped once at the end of each 8 hr day at which time BOD concentration may reach 40,000 ppm in the first bowl. The BOD concentration in each succeeding bowl is usually about 10 percent of that in the previous bowl. The scouring process contributes 55-75 percent of the total BOD. About half of the raw wool weight is removed in scouring.

2. Dyeing: The wool may be dyed either before or after the weaving process. If done before, it is called stock or yarn dyeing. If done after, it is called piece dyeing. Because of the current popularity of multi-color woven fabric, yarn or stock dyeing is prevalently used.

Currently, stock and yarn are usually dyed in pressure vessels with controlled liquid recirculation by pumping. Formerly, older stock and yarn dyeing processes used open vats where paddles moved the wool through the dye bath. Although spool and skein dyeing are both in current use, most wool is dyed in skeins, placed in packages, and then rewound.

The dyeing and printing processes are very difficult to classify or discuss because of the very great differences in the types of dyes used and the manner in which any one type of dye is applied to the goods. The dye wastes are all large in volume and high in color, and many of them are toxic.

For wool, a dyeing assistant is generally used and often is the source of an additional pollutional load.

3. Carding: The general process by which scoured wool fibers are aligned for spinning into yarn is known as carding. This process is a "Dry" process in that water is not used and therefore no wastes are discharged. Wool fiber must be oiled before it is carded, spun and woven to increase cohesion of the fibers and to facilitate related processes. The carding oil remains on the wool while it is being spun and woven into cloth on looms. It is washed out following the fulling process.

4. Fulling: Fulling is a felting process which shrinks, tightens, and smooths the wool either for non-woven felts or woven cloth. No wasteload is generated directly, but subsequent washing creates waste substances.

The wool is first impregnated with a fulling agent which may be soap, acid, or a synthetic chemical and subjected to heat and pressure. The agent is added in amounts varying from 2 to 10 percent OWF (of weight fiber). The wool is then rotated in a fulling machine until the desired extent of shrinkage and felting are achieved.

5. Washing: After fulling, the residual waste materials, which may amount to about 10-25 percent OWF, are washed out of the cloth, generally in a string or rope washer. The cloth is pulled between the rollers of the washer, then its ends are sewn together to form a string which circulates through the washer 10 to 20 times. The bottom of the washer is filled with a detergent solution (soap or synthetic) through which the cloth passes in its cycle. After completing this initial wash cycle, the detergent solution is drained and the cloth is circulated while being sprayed with clean water. The rinse rate on most machines is usually 15,000 to 40,000 gal/hr. In some plants, the cloth is re-cycled through a second wash and rinse. In either case, the amount of water used per 1000 lb of wool averages about 40,000 gal and may reach 100,000 gal.

Washing after fulling is the second largest source of BOD, contributing about 20 to 35 percent of the total. The volume of wastewater discharged is about 65 percent of the total. The concentration of BOD in the detergent solution varies from 4000 to 11,500 ppm.

6. Carbonizing: Carbonizing of fabrics is a common finishing process which removes any traces of vegetable matter remaining on the wool.

The wool is first wet out, then immersed in 4-6 percent sulfuric acid. The wool is squeezed between rollers to remove excess acid and heated to 212° - 220°F. At this temperature, the vegetable matter is charred and loosened. The wool is again squeezed between rollers and shaken in a duster to remove the charred particles.

Acid removal is achieved by preliminary rinsing and neutralization in 2 1/2% sodium carbonate solution. The wool is then subjected to a final running rinse to remove all traces of alkalinity.

The BOD comes entirely from the vegetable matter and the amount contributed by this process is very small, usually less than 1 percent of the total.

7. Bleaching: The bleaching operation may be done after the scouring process (often in the last bowl of the scouring train) or it may be done after finishing. In either case the percentage of wool bleached is very small and the contribution to plant BOD is low,

(usually less than 1/2 percent).

Wool may be bleached by reduction of color compounds with sulfur dioxide which is not a permanent bleach. A true bleach is obtained by the use of hydrogen peroxide mixed with sodium for pH control. Another bleach employs sodium peroxide with acid for pH control.

Many plants use optical brighteners composed of various organic compounds. Although the BOD load is generally higher than for other methods, this process still contributes less than 1 percent of the total BOD.

B. Significant Pollutants

The major sources of pollution in the wool production process are scouring, dyeing and washing.

The pollution load from the scouring process is extremely high in BOD and grease, has a turbid brown color due to the large amounts of dirt and grease, has a generally high alkalinity, and a temperature between 115°F and 125°F.

Dyeing produces an acid waste which is highly colored and relatively high in BOD. It may also be slightly toxic depending on the type of dye used.

Wastes from the wash after fulling contain a high concentration of BOD and oil. In addition, these wastes have temperatures ranging from 110° to 150°F.

C. Process Water Reuse - 1964

The amount of process water reused in 1964 was considerably greater than in 1950 when older methods were practiced. Counter-current scouring can reduce the amount of water required by as much as 6000 gal/1000 lb of wool. Reuse of rinse waters in the wash after fulling can reduce water requirement by approximately 4000 gal/1000 lb of wool. We estimate that in 1964 the wool industry as a whole reused approximately 5 percent of its process water, and 95 percent was used only once.

D. Subprocess Trends

The projections on Table I-1 are based on a general industry trend toward the use of more synthetic chemicals as the technology approaches its goal of better product quality at lower cost.

TABLE I-1
SUBPROCESS TRENDS

Production Process and Significant Subprocesses	Estimated Percentage of Plants Employing Process in:				
	1950	1963	1967	1972	1982
Scouring					
Soap/alkali	80	0	0	0	0
Syndet	0	80	50	40	30
Non-ionic syndet	0	0	40	50	65
Solvent	20	20	10	10	5
Dyeing					
Sodium Sulfate	100	100	100	100	100
Sulfur Dioxide	40	10	5	0	0
Hydrogen Peroxide	40	70	75	85	95
Acetic Acid	20	20	20	15	5
Sulfuric Acid	100	100	100	100	100
Carding					
Olive Oil	20	0	0	0	0
Synthetic Oil*	80	100	100	100	100
Fulling					
Soap	95	10	0	0	0
Synthetic Chemicals	0	70	80	90	100
Sulfuric Acid	5	20	20	20	0
Washing					
Soap	100	0	0	0	0
Syndet	0	100	100	100	100
Carbonizing					
Sulfuric Acid	100	100	100	100	100

* 20 percent BOD content by weight

E. Waste Control Problems

Of all the textile wastes, wool scouring wastes are generally considered the most difficult to treat. Raw wool contains an average of about 50 percent impurities and fibers. Approximately 50 percent of these impurities are wool grease (lanolin), 20 percent suint, 20 percent inert dirt, and 10 percent vegetable matter. The impurities are easily dissolved in water, except for the grease. In an average plant, 50 to 60 lb of chemicals (detergents, alkali, softeners, etc.) are used for each 1000 lb of scoured wool. The total wasteload is, therefore, composed of 1000 lb of grease, suint, and dirt; plus 50 to 60 lb of chemicals, or 1050 to 1060 lb of total solids for each 1000 lb of wool scoured.

Costs of treating this effluent by chemical means is relatively high and treatment by biological means is not feasible without pretreatment for grease removal. Chemical or mechanical methods can be used to remove grease. However, the process is an economical burden due to the lack of a market for recovered grease.

Solvent scouring is a technically feasible method of grease removal. In the solvent scouring method, the grease is removed in the solvent distillery and the spent solvent is distilled and reused. However, the lack of a market for grease creates a financial bias against this process.

F. Subprocess Technologies

1. Older Technology: Older technology is the procedure followed by the majority of wool mills in the year 1950.

Scouring: Grease wool is scoured in a 3 to 5 bowl scouring train or in 3 to 5 separate bowls in which wool is washed in batches. Soap and soda ash are used in the first 2 or 3 bowls with clean water in the remaining bowls. The last bowl is a continuously running overflow rinse which is not recirculated or reused in any way.

Stock Dyeing: Dyeing is done in sunken open top kettles containing acetic acid (62 percent BOD OWC) and dye solution. The wool is placed in wire mesh baskets with slow moving paddles and immersed in the solution.

Carding: Due to shortages, low BOD carding oils were developed during World War II and were found to be as good as, or better than, olive oil. Further improvements in these synthetic oils had made their use normal practice by 1950.

Fulling: Soap is generally used as a fulling agent, often mixed with small amounts of soda ash. The cloth is immersed in the fulling solution then passed through squeeze rollers which remove any excess, allowing 5 to 10 percent OWF of the solution to remain in the cloth.

Washing: Soap and soda ash plus softening agents are used in the string washer in which approximately 46,000 gal of water are used for each 1000 lb of wool. Rinse water is generally not reused.

Carbonizing: Carbonizing is done with a 6 percent sulfuric acid solution and 212°F oven. Crushing and dusting are done mechanically and neutralization is achieved by immersion in a soda ash solution. The wool is rinsed before and after neutralization with 16,000$^{\pm}$ gal of water/1000 lb of wool.

Bleaching and Piece Dyeing: Bleaching is done in the dye kettles generally using hydrogen peroxide. The latter usually require heating to 115°F for at least 3 hours in order to obtain a good bleach. Piece dyeing is rare, but the procedure and process chemicals are similar to those used for stock dyeing of wool fibers.

2. Prevalent Technology: The production procedure followed by typical plants in the base year (1963) can be broken down in the following order:

Scouring: Depending on the size of the plant, grease wool is initially scoured in a 3 to 5 bowl train using a low BOD 12 percent OWC (of weight chemical) synthetic detergent in the first 2 or 3 bowls. The rinse water from the last bowl (or bowls) is recirculated in a counterflow operation.

Stock Dyeing: The scoured wool is normally stock dyed in pressure kettles using ammonium sulfate or sulfuric acid and sodium sulfates, plus dye solution. The type of dye used depends on the color desired, fastness to light and water, and other properties.

Carding: A low BOD oil (approximately 20 percent OWC) is sprayed onto the fiber while it is being mixed, in amounts ranging from 1 to 8 percent. The fiber is then drawn, spun,and woven into cloth.

Fulling: The wool cloth is passed through an impregnating box containing a synthetic fulling agent of low BOD (about 12 percent OWC). The amount added (amount remaining in cloth) depends on the degree of felting desired, and usually falls in a range of 5 to 10 percent OWC.

Washing: A low BOD (12 percent OWC) synthetic detergent is used in a string washer in which the entire wash-rinse cycle is carried out twice to insure complete removal of the oil and fulling agent. Some of the rinse water is recirculated and used to make the detergent solution.

Carbonizing: The wool is carbonized with a 6 percent sulfuric acid solution and oven heating to 212°F. It is neutralized by soaking in a soda ash solution followed by a running rinse of 16,000 gal/1000 lb of wool.

Bleaching and Piece Dyeing: The small percentage of wool cloth which is to remain white is bleached with sulfur dioxide or hydrogen peroxide in vats which are also used for dyeing. Some plants may bleach in the last bowl of the scouring train before the fiber is woven.

Optical brightening, using acetic acid and fluorescent organic compounds, is used in many mills. Some mills may do a small amount of dyeing in small dye becks following all finishing processes.

3. Newer More Advanced Technology:

Scouring: The grease wool is packed into large vacuum kiers and scoured with methyl alcohol to remove suint salts. The wool is then scoured with isopropyl or ethyl alcohol to remove grease. The spent solvent can be distilled for reuse and grease recovery. Finally, the wool is washed in water to remove dirt and other soluble particles remaining on the fiber.

Stock Dyeing: Scoured wool is stock-dyed by a continuous process using pressure equipment similar to a scouring train but with 8 compartments, and automatic controls to prevent or control felting. Ammonium sulfate and dye solution are used in various concentrations in the compartments.

Carding: Low BOD carding oils (less than 3 percent OWC) are added in amounts of 1 to 8 percent OWF.

Fulling: The fulling agents used are either synthetic chemicals or sulfuric acid - hydrogen peroxide combinations. Fulling is still done in tubs with beating-action rollers. This type of equipment has been in use for many years.

The fulling solution is completely neutral and contributes no BOD in itself. Spray rinsing with recirculation or a running rinse in a continuous piece washer may be used.

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Carbonizing: Traditional methods of carbonizing have not been improved to the extent of reducing the pollution loads; however, some water reuse in rinsing may be practiced.

Bleaching and Piece Dyeing: Traditional methods of bleaching and piece dyeing are followed in newer, technologically advanced plants.

4. Plant Classification

The percentage of plants falling into each of the three technology levels is estimated as follows:

Older	20 percent
Prevalent	70 percent
Newer	10 percent

Plant sizes are classified as follows:

Small	Less than 5,000 lb/week
Medium	5,000 to 20,000 lb/week
Large	More than 20,000 lb/week

The relative proportion of small, medium and large plants included in each technology level are estimated as follows:

	Older	Prevalent	Newer
Small	40%	58%	2%
Medium	15	75	10
Large	10	78	12

II. GROSS WASTE QUANTITIES

A. Daily Waste Quantities

The average production of wool scouring and finishing mills has been estimated at 3000 lb/day of finished wool cloth. The following table is based on this estimate and assumes that average production is identical for all 3 levels of technology.

TABLE II-1

DAILY WASTE QUANTITIES
PLANT PRODUCING 3000 lb/day

	TECHNOLOGY LEVEL					
	OLDER		PREVALENT		NEW	
	BOD lb	GAL	BOD lb	GAL	BOD lbs	GAL
Scouring	760	24,800	680	6,200	31	1,500-6,200
Dyeing	152	9,300	31	9,300	28	9,300
Washing	465	144,000	198	130,000	93	130,000
Carbonizing	6.2	49,600	6.2	49,600	6.2	49,600
Total	1,383.2	227,700	915.2	195,100	158.2	190,450-195,100

This table indicates that BOD wastes will decrease markedly with the introduction of each newer level of technology in all processes except carbonizing. At present it also indicates that there is little reduction in waste quantities except in the scouring process where significant reductions may be achieved with the solvent scouring method. Unfortunately, this process is not in widespread use in the industry.

B. Wasteload Production Rates

Wasteload production rates for the wool finishing industry were derived by averaging information from several published sources. These averages are shown in the following tabulation:

WASTE	TECHNOLOGY LEVEL OLD	PREVALENT	NEW
BOD lb/1000 lb	451	296	51
Gal/1000 lb	73,700	63,000	61,500-63,000

In the above table, BOD figures are provided by Masselli and Burford[1]. The BOD reductions between older and prevalent technology levels are due to substitution of process chemicals. The additional BOD reduction between prevalent and new technology levels is due to better recovery of grease and suint. According to the above reference, these methods produce up to 89 percent overall BOD reduction. About 23 percent overall reduction in wastewater generated is possible by means of current water reuse, conservation, and process improvements. Further advances can be achieved with improved technology.

C. Total Wasteload

Statistics provided by the U.S. Department of Commerce reveals that 412 million lb of wool (scoured basis) were consumed by mills in 1963. Based on this data and wasteload quantities from Section II B, we estimate that in the base year 1963, the wool weaving and finishing industry discharged approximately 26 billion gal of wastewater. The total BOD produced was approximately 132 million lb, at an average concentration of 565 ppm. In addition, approximately 310 million lb of grease were removed from the raw wool.

D. Gross Wasteload Projections

The following projections assume a continuous adaptation of new techniques as they are developed, resulting in lower water requirements and less pollution.

GROSS WASTELOAD PROJECTIONS

Item	1968	1969	1970	1971	1972	1977	1982
BOD - Million lb	132.8	132.9	133.0	133.2	133.2	134.2	136.0
Wastewater-Billion gal	28.30	28.32	28.35	28.40	28.40	28.60	29.00

E. Seasonal Variation

There appear to be no significant seasonal variations in the wool finishing industry. The raw wool is stored and used as required by the wool finishing industry.

III WASTE REDUCTION PRACTICES

A. Processing Practices

The following Table III-1 outlines the relative pollution reduction potentials of the various alternative subprocesses used in the industry. The "older" technological method in each case is used as a base to which all others are compared.

TABLE III-1

PROCESS POLLUTION REDUCTION

Process and Subprocesses	BOD lb/ 1000 lb	Waste Reduction Effectiveness (%)	Remarks
Scouring			
Soap/Alkali	250	0	
Syndet	221	11.6	Syndet denotes Synthetic Detergent
Solvents	10	96	
Dyeing			
Acetic Acid	49	30	
Ammonium Sulfate	10	86	
Sulfuric Acid	70	0	
Washing			
Soap/Alkali	150	0	
Syndet	64	57.3	20 percent BOD oil used for carding
Syndet	30	80	BOD reduction due to use of 3 percent BOD oil in carding
Carbonizing			
Sulfuric Acid plus Sodium Carbonate	2	0	

III. WASTE REDUCTION PRACTICES (cont'd)

B. Treatment Practices

1. Removal Efficiencies

Table III-2 shows removal efficiencies of various waste treatment methods. Based on a typical waste generated by prevalent plants in the base year 1963, the removal efficiencies are expressed in terms of percentage of gross wasteload removed by the removal process.

TABLE III-2

TREATMENT REMOVAL EFFICIENCIES

Treatment Method	Normal Reduction Percent				
	BOD	Grease	Color	Alkalinity	SS
Grease Recovery					
Acid Cracking	20-30	40-50	0	0	0-50
Centrifuge	20-30	24-45	0	0	40-50
Evaporation	95	95	0	0	
Screening	0-10	0	0	0	20
Sedimentation	30-50	80-90	10-50	10-20	50-65
Flotation	30-50	95-98	10-20	10-20	50-65
Chem. Coagulation					
$CaCl_2$	40-70				80-95
Lime + $CaCl_2$	60	97			80-95
CO_2 - $CaCl_2$	15-25				80-95
Alum	20-56*		75		
Copperas	20*				
H_2SO_4+ Alum	21-83*				
Urea + Alum	32-65*				
H_2SO_4+ $FeCl_2$	59-84*				
$FeSO_4$	50-80				
Activated Sludge	85-90	0-15	10-30	10-30	90-95
Trickling Filtration	80-85	0-10	10-30	10-30	90-95
Lagoons	0-85	0-10	10-30	10-20	30-70

2. Rate of Adoption

The most common practices of waste treatment in the wool industry are biological methods,such as sedimentation, activated sludge, trickling filtration, and lagooning. Screening is almost universally used to remove fibers which may possibly damage subsequent treatment facilities. Equalization and holding is generally necessary due to batch dumping of many of the process wastes creating shock loads and intermittent flows through the treatment system.

In the past, wool wastes were treated by chemical precipitation without pre-treatment for grease recovery; however, the present trend is towards biological oxidation and chemical pre-treatment due to economic factors.

Work in recent years by Souther and others indicates clearly that the activated sludge process with modifications (primarily extended aeration time and influent pH adjustment) will consistently produce BOD reductions on the order of 90 percent. As the discharge requirements imposed upon the textile finishing plants are upgraded, it is probable that future waste treatment facilities will be predominately of the activated sludge type.

The percentage of wool finishing wastes treated by municipal plants is also increasing steadily as costs of building and maintaining in-plant treatment facilities increase. Newer finishing mills are being built close to municipalities rather than in rural areas to take advantage of the availability of municipal treatment.

Much of this industry's waste is discharged to municipal sewers because they are often located adjacent to or within population centers. As these population centers expand, more sewers become available to the industry, as indicated below:

3. Discharge to Municipal Sewers

Percentage of Industry Waste Discharged to Municipal Sewer

Year	1950	1963	1967	1972	1977	1982
Percent	34	40	60	70	75	80

Industry wastes are generally pretreated by grease removal techniques and screening prior to discharge into a municipal system. Municipal waste treatment plants are not equipped to easily handle the large amounts of grease produced by wool mills. Screening for removal of fibers is also necessary to prevent clogging of biological treatment equipment and to reduce the quantity of suspended matter. Carrying rates of waste production require holding tanks and surge basins to minimize peak discharge and provide for more or less uniform rates of release to sewers. Municipal treatment without pre-treatment may be feasible in the case of high capacity chemical coagulation treatment plants.

C. By-Product Utilization

By-product utilization, as previously indicated, depends on economic considerations. It is estimated that 50,000 to 100,000 tons of wool grease and 20,000 to 40,000 tons of suint could be utilized if the market for these products made it economically feasible. Lanolin is recovered from the wool grease and potash from the suint.

D. Net Waste Quantities - 1963

It is estimated that the wool industry discharged 26 billion gal of waste water in 1963. Of this amount, an estimated 5.5 billion gal were treated by industry-owned and-operated waste treatment facilities and an additional 10 billion gal were treated in municipal facilities, totaling 15.5 billion gal treated.

In Section II.A, the gross BOD production was estimated at 132 million lb during 1963. Based upon waste pretreatment processes then in effect, it is estimated that BOD removal efficiencies by industry-operated plants averaged 70 percent, and municipally-operated plants averaged 85 percent. On this basis the net BOD pollution load reaching water courses from the wool finishing industry in 1963 equaled 70 million lb of BOD.

E. Projected Net Waste Quantities

Table III-3 is a summary of the projected net waste quantities reaching watercourses. It is based upon the previously projected gross waste produced, rate of construction of treatment facilities by industry, higher percentage of waste going into municipal sewers, and improved techniques of waste treatment by industry and municipalities.

TABLE III-3

PROJECTED NET WASTELOADS

Year	Gross Waste Generated BOD million lb	Waste Treated Municipally percent	Average Reduction percent	Waste Treated By Industry percent	Average Reduction percent	Untreated Wastes percent	Total Reduction percent	Net Waste Discharged BOD million lb
1963	132	38.5	85	21.0	70	40.5	47.4	69.4
1967	132.5	40.0	86	23.0	71	37.0	50.7	65.4
1968	132.8	40.5	86	23.5	71	36.0	51.5	64.5
1969	132.9	41.0	86	24.0	71	31.0	52.4	63.3
1970	133.0	41.5	87	24.5	72	34.0	53.7	61.6
1971	133.1	42.0	87	25.0	72	33.0	54.6	60.4
1972	133.2	42.5	87	25.5	73	32.0	55.4	59.4
1977	134.2	45.0	88.5	28.0	74	27.0	60.6	52.9
1982	136	48.0	90	31.0	76	21.0	66.8	45.1

IV. COST INFORMATION

A. Existing Facilities Costs

Most wool finishing mills have at least some waste treatment facility. In the majority of cases it is grease removal and screening prior to discharge into a sewer, lagoon, or watercourse.

We estimate that the replacement value of industry-owned and-operated treatment facilities in 1966 was $9.0 million.

The operation and maintenance expenditures in 1966 are estimated at $5.0 million.

It must be noted that the above values are for industry owned and operated plants only. We estimate that in 1966 approxmately 40 percent of the waste flow was treated by municipal facilities. Since industry pays taxes and surcharges to support these facilities,the true industry cost exceeds the foregoing amounts.

We estimate that the replacement value of that portion of municipal treatment facility construction attributable to this industry waste is $10 million. On the same basis the annual operating and maintenance cost is estimated at $4.0 million.
Totals: Replacement Value: $19 million.
Operation & Maintenance $9.0 million.

B. Processing and Treatment Costs

This portion of the survey analyzes costs involved in subprocesses and end of line treatment. These are further broken down into size of plant and state of technology; i.e., older, prevalent, and newer. Because of the wide ranges in the information feedback from the wool finishing industry, we have inserted ranges in the following tables.

It should be noted that new machinery for subprocesses is usually purchased by the industry on the basis of increasing production efficiency and product quality - not on the basis of decreasing the pollution load produced by the subprocess. Any such decrease is merely a bonus in most cases.

It should also be noted that the end of the line waste treatment has virtually no relationship to the technology of the process that created the waste or the size of the finishing plant; i.e., an older technology plant may have an extremely efficient, modern, waste treatment facility and a modern, efficient finishing plant may have no waste treatment facility at all. With few exceptions the end of the line treatment is selected primarily on the basis of requirements imposed by regulating agencies responsible for the watercourses being affected.

It should also be noted that we are required to estimate costs for plants incorporating pure states of technology; i.e., completely old, completely prevalent, completely advanced. Few such plants exist. Most plants are mixtures of varied subprocess technologies since they have been modernized in stages over a relatively long period of time.

SEVERAL DEFINITIONS ARE NECESSARY TO UNDERSTAND THE FOLLOWING TABLES.

Old technology -that technology new in 1950

Prevalent technology-that technology new in 1963

Advanced technology -that technology new in 1967

Small plant - processing less than 5000 lb per week

Medium plant - processing from 10,000 to 20,000 lb per week

Large plant - processing over 20,000 lb per week

Capital cost - same as original new cost

Annual Operating and Maintenance Cost - in 1966

Economic Life - the economic life is the length of time the machine or structure can be expected to compete with advancing technology. It is an estimate of the length of time required for economic obsolescence. This will vary greatly in different industries depending upon the nature of the product, dynamics of industry growth, etc.

TABLE IV-1 COSTS: SMALL PLANT (5000 lb/week)
OLD TECHNOLOGY (1950)

Item	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
	($1000)	($1000)	(Years)
Alternative Subprocesses			
Scour	50- 70	30- 40	10
Stock Dyeing	20- 30	15- 25	10
Carding	30- 50	25- 40	10
Fulling	10- 20	10- 20	10
Fulling Wash	5- 15	5- 10	10
Bleach & Piece Dyeing	10- 20	15- 25	10
Rest of Plant	75- 95	20- 40	10
Total	200-300	120-200	
End of Line Treatment			
Grease Recovery	4.5-7.5	2.0-4.0	10
Screening	0.7-3.6	0.2-0.4	10
Sedimentation	1.6-4.5	0.3-0.7	10
Chemical Precipitation	3.6-7.2	1.8-3.6	10
Flotation	2-5.4	0.4-0.9	10
Trickling Filter	6.3- 14	0.9-2.2	10
Activated Sludge	8- 33	1.3-3.6	10
Lagooning	.5-1.8	0.1-0.2	10
Sludge Disposal	-	0.7-2.5	-

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-2 COST: MEDIUM PLANT, (20,000 lb/week)
OLD TECHNOLOGY (1950)

Item	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
	($1000)	$1000)	(Years)
Alternative Subprocesses			
Scour	130-170	110-140	10
Stock Dyeing	55- 80	60- 90	10
Carding	95-130	90-120	10
Fulling	35- 50	40- 80	10
Fulling Wash	30- 40	20- 40	10
Bleach & Piece Dyeing	40- 70	60-100	10
Rest of Plant	270-370	120-130	10
Total	655-910	500-700	
End of Line Treatment			
Grease Recovery	9-14	3.9-7 7	10
Screening	1.4- 7	0.3-0.7	10
Sedimentation	3.2- 9	0.5-1.4	10
Chemical Precipitation	7-14	3.5-7	10
Flotation	3.8-11	0.7-1.8	10
Trickling Filter	12-28	1.8-4.2	10
Activated Sludge	16-42	2.4-7	10
Lagooning	1-3.5	0.2-0.4	10
Sludge Disposal	-	1.4-4.9	-

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

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TABLE IV-3 COSTS: LARGE PLANT (50,000 lb/week)
OLD TECHNOLOGY (1950)

Item	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
	($1000)	($1000)	(Years)
Alternative Subprocesses			
Scour	280- 360	250- 320	8
Stock Dyeing	120- 200	120- 200	8
Carding	200- 280	200- 280	8
Fulling	80- 120	80- 160	8
Fulling Wash	60- 100	40- 80	8
Bleach & Piece Dyeing	80- 160	120- 200	8
Rest of Plant	580- 780	190- 260	10
Total	1400-2000	1000-1500	
End of Line Treatment			
Grease Recovery	19-33	8.6-17	10
Screening	3.2-16	0.8-1.6	10
Sedimentation	7.2-20	1.2-3.2	10
Chemical Precipitation	16-32	8-16	10
Flotation	8.8-24	1.6-4	10
Trickling Filter	28-64	4-9.6	10
Activated Sludge	36-96	5.6-16	10
Lagooning	2.4-8	0.4-0.8	10
Sludge Disposal	-	3.2-11	-

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-4 COSTS: SMALL PLANT (5000 lb/week)
PREVALENT TECHNOLOGY (1963)

Item	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
	($1000)	($1000)	(Years)
Alternative Subprocesses			
Scouring	-[1]	100-130 (Wool Purchased) (Scoured)	-[1]
Stock Dyeing	40-65	13-22	7
Carding	65-90	22-32	7
Fulling	25-40	10-18	5
Wash After Fulling	20-35	4-10	6
Bleaching & Piece Dyeing	25-50	13-22	8
Rest of Plant	190-250	18-36	10
Total	365-530	180-270	
End of Line Treatment			
Grease Recovery	-[1]	-[1]	-[1]
Screening	0.7-3.3	0.1-0.4	10
Sedimentation	1.5-4.2	0.2-0.7	10
Chemical Precipitation	3.3-6.7	1.7-3.3	10
Flotation	1.8-5	0.3-0.8	10
Trickling Filter	5.8-13	0.8-2	10
Activated Sludge	7.5-20	1.2-3.3	10
Lagooning	0.5-1.7	0.1-0.2	10
Sludge Disposal	-	0.7-2.3	-

1. Scoured Wool is Purchased from Commission Houses

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-5 COSTS: MEDIUM PLANT (20,000 lb/week)
PREVALENT TECHNOLOGY (1963)

Item	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
	($1000)	($1000)	(Years)
Alternative Subprocesses			
Scouring	170- 220	75- 95	6
Stock Dyeing	70- 105	40- 60	7
Carding	125- 170	60- 85	7
Fulling	45- 65	25- 50	5
Wash After Fulling	40- 50	15- 25	6
Bleaching & Piece Dyeing	50- 90	40- 70	8
Rest of Plant	350- 480	45- 95	10
Total	850-1180	300-480	
End of Line Treatment			
Grease Recovery	8-13	3.5-7.1	10
Screening	1.3- 6	0.3-0.6	10
Sedimentation	2.9- 8	0.5-1.3	20
Chemical Precipitation	6.4-13	3.2-6.4	15
Flotation	3.5-10	0.6-1.6	20
Trickling Filter	11-26	1.6-3.9	20
Activated Sludge	14-39	2.3-6.4	20
Lagooning	1-3.2	0.2-0.3	20
Sludge Disposal	-	1.3-4.5	-

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-6 COSTS: LARGE PLANT (50,000 lb/week)
PREVALENT TECHNOLOGY (1963)

Item	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
	($1000)	($1000)	(Years)
<u>Alternative Subprocesses</u>			
Scouring	365- 470	165-220	6
Stock Dyeing	155- 260	85-135	7
Carding	260- 365	105-130	7
Fulling	105- 155	50-105	5
Wash After Fulling	80- 130	25-55	6
Bleaching & Piece Dyeing	105- 210	10-135	8
Rest of Plant	750-1000	110-220	10
Total	1820-2590	550-1000	
<u>End of Line Treatment</u>			
Grease Recovery	19-31	8-16	10
Screening	3-15	0.7-1.5	10
Sedimentation	5.7-19	1.1-3	20
Chemical Precipitation	15-30	7.4-15	15
Flotation	8-22	1.5-3.7	20
Trickling Filter	26-59	3.7-9	20
Activated Sludge	33-89	5.2-15	20
Lagooning	2.2-7.4	0.4-0.7	20
Sludge Disposal	-	3-10	-

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does <u>not</u> include any sewer <u>collection</u> system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-7 COSTS: - SMALL PLANT (5,000 lb/week)
NEWER TECHNOLOGY (1967)

Item	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
	$1000)	($1000)	(Years)
Alternative Subprocesses			
Scouring	-[1]	110-140 (Wool Purchased Scoured)	-[1]
Stock Dyeing	50- 70	15- 20	7
Carding	70-100	20- 30	7
Fulling	25 - 45	10- 15	7
Wash After Fulling	20 - 35	5- 10	5
Bleaching & Piece Dyeing	30- 55	15- 25	8
Rest of Plant	205-270	15- 35	10
Total	400-575	190-275	
End of Line Treatment			
Grease Recovery	-[1]	-[1]	-[1]
Screening	0.6.-3	0.2-0.3	10
Sedimentation	1.4-3.8	0.2-0.6	20
Chemical Precipitation	3-6	1.5-3	15
Flotation	1.6-4.5	0.3-0.8	20
Trickling Filter	5.2-12	0.8-1.8	20
Activated Sludge	6.8-18	1-3	20
Lagooning	.5-1.5	0.1-0.2	20
Sludge Disposal	-	0.6-2.1	-

1. Scoured Wool is purchased from Commission houses.

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does <u>not</u> include any sewer <u>collection</u> system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-8 COSTS: MEDIUM PLANT (20,000 lb/week)
NEWER TECHNOLOGY (1967)

Item	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
	($1000)	($1000)	(Years)
Alternative Subprocesses			
Scouring	180- 240	70- 90	5
Stock Dyeing	75- 110	35- 60	7
Carding	140- 180	60- 80	7
Fulling	50- 70	25- 50	5
Wash After Fulling	40- 55	15- 25	6
Bleaching & Piece Dyeing	55- 95	40- 65	8
Rest of Plant	380- 520	45- 90	10
Total	920- 1270	290-460	
End of Line Treatment			
Grease Recovery	7.4-12	3.2-6.5	10
Screening	1.2- 6	0.3-0.6	10
Sedimentation	2.7- 7	0.4-1.2	20
Chemical Precipitation	5.9-12	2.9-5.9	15
Flotation	3.2- 9	0.6-1.5	20
Trickling Filter	10.3-24	1.5-3.5	20
Activated Sludge	13-35	2.1-5.9	20
Lagooning	0.9- 3	0.1-0.3	20
Sludge Disposal	-	1.2-4.1	-

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-9 COSTS: LARGE PLANT (50,000 lb/week)
NEWER TECHNOLOGY (1967)

Item	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
	($1000)	($1000)	(Years)
Alternative Subprocesses			
Scouring	390- 505	155-210	5
Stock Dyeing	170- 280	80-130	7
Carding	280- 390	130-180	7
Fulling	110- 170	55-105	5
Wash After Fulling	80 - 140	25-55	6
Bleaching & Piece Dyeing	110- 225	80-130	8
Rest of Plant	810-1090	105-210	10
Total	1950-2800	630-1020	
End of Line Treatment			
Grease Recovery	17-28	7.4-15	10
Screening	2.7-13	0.7- 1.3	10
Sedimentation	6-17	1- 2.7	20
Chemical Precipitation	13-26	6.7-14	15
Flotation	7.4-20	1.3- 3.4	20
Trickling Filter	24-54	3.4- 8.1	20
Activated Sludge	30-81	4.7- 14	20
Lagooning	2-6.7	0.3- 0.7	20
Sludge Disposal	-	2.7- 9.4	

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-10

SUMMARY OF PRODUCTION AND WASTE TREATMENT COSTS

Wool Textile Weaving and Finishing*

Item	Quantity
Total Production	412 Million lb
Total value added in manufacture	392 Million $
Average unit value added in manufacture[2]	0.95 $/ lb
Estimated replacement value of waste reduction facilities[3]	19 Million $
Annual amortized cost of facilities at 7% and 10 yr life[3]	2.7 Million $
Estimated annual waste reduction operating and maintenance cost[3]	5.0 Million $
Average industry cost[1] of waste treatment per unit of production	.0194 $/lb
Total waste reduction costs as percent of total production cost	2 Percent

The above table is a comparison of the total capital, operating, and maintenance cost per year of end of the line waste treatment to the total cost of production per year. These are industry-wide estimates and individual plants may deviate considerably.

1. Not including grease recovery costs, which may increase total waste reduction costs by 50 percent or more, depending upon the prevailing market for wool grease.

2. From the Business and Defense Services Administration, U. S. Department of Commerce, 1967.

3. Estimated replacement value, estimated amortization, and estimated annual operating costs include an estimate of the cost of municipal treatment facilities attributable to this industry's waste.

WOOL TEXTILE WEAVING AND FINISHING

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Industrial Waste Profile

Cotton Textile Finishing - SIC 2261

U. S. Department of the Interior
Federal Water Pollution Control Administration
I.W.P. No. 4 - Cotton Textile Finishing

INDUSTRIAL WASTE PROFILE STUDIES
TEXTILE INDUSTRY

SIC NO. 2261, COTTON INDUSTRY

INTRODUCTION

Cotton fiber is the single most popular and important fiber in the American textile industry. Its excellent absorptive and use characteristics, as well as reasonable price, contribute to the stable market of about 7-9 million bales per year consumed during the past decade; this quantity represents approximately one-half of the total fiber used by our textile industry. The wool and rayon market is also reasonably stable, while non-cellulosics synthetic fibers have markedly increased their domestic consumption from approximately 3 million bales equivalent in 1957 to some 6 million bales equivalent annually in 1966. Cotton mixtures in blend with synthetics are becoming increasingly popular because of the resulting cost, appearance and utilitarian features.

Our cotton industry has been traditionally dependent on low labor costs to meet competition from abroad. However, industry leaders are developing newer, more efficient, larger production yield equipment to replace the older, less efficient subprocess facilities in order to overcome domestic labor problems, synthetic fiber and expanding foreign competition. It is also interesting to observe that cotton production has partially shifted from the southern United States into the irrigated lands of the western United States. The United States exported over 5 million bales of cotton in 1964 alone. The cotton industry is expanding in both research and promotion in order to compete with the well publicized synthetic fibers.

Cotton textile mills produce a strong waste, particularly from sizing, dyeing and wet finishing operations. The highly mineralized, toxic wastes of the cotton industry have proven partially amenable to limited types of biological, chemical and mechanical treatment processes. A few industry leaders in the eastern United States have, in limited cases, installed and operated modern, complete waste treatment plants which are doing an outstanding waste management job at a reasonable cost.

INDUSTRIAL WASTE PROFILE STUDIES
TEXTILE INDUSTRY

SIC 2261, COTTON INDUSTRY

I. PROCESSES AND WASTES

A. Fundamental Processes

1. Conversion to Cloth
2. Desizing
3. Scouring or Boil-off
4. Bleaching
5. Mercerizing or Causticizing
6. Dyeing
7. Finishing

Conversion to cloth is usually achieved in a weaving mill. However, our primary interest lies in the finishing mill which is the major source of wet wastes in the cotton processing industry. The following outline describes industry practices over the past twenty years.

1. Conversion to Cloth: All the processes involved in converting raw cotton to woven cloth are "dry". However, they interest the waste engineer because they add impurities to the fiber. It is carded, spun, spooled and made into warp, slashed, drawn, and woven or knitted into cloth before being sent to the finishing mill as "grey goods". The slashing process is the only non-mechanical operation. In slashing, the warp thread is sized to impart tensile strength and smooth finish to prevent warp breaks. The size is dried on the thread and remains as part of the cloth until removed in the finishing mill. Although starch is usually used for sizing (especially for the fine woven fabrics), other chemicals such as polyvinyl alcohol, resins, alkali-soluble cellulose derivatives, gelatin glue, locust bean gum, and gum tragacanth, have been used. One of these, sodium carboxymethylcellulose, or CMC, is finding some acceptance as a starch substitute, showing its most rapid growth in the polyester blend sizing area. Other chemicals, such as lubricants, softeners, emulsifiers, humectants, preservatives ($ZnCl_2$, phenol, etc.), penetrants, anti-foam agents, and fillers, are often added to impart additional properties to the film. The grey goods thus prepared usually contain about 10 to 15 percent add-on, mostly sizing.

"Grey goods" are brushed and sheared to remove lint, dust, loose yams, loops and hanging ends. After inspection for defects, the fabric is singed by passing it over a heated plate or roller or between gas flames to remove fuzz and obtain a smooth surface. No liquid wastes are involved.

2. Desizing: Cloth is desized by either the enzyme process, high temperature enzyme process, or simply water. Denim and duck are generally not desized. The enzyme solution (usually from 1/4 to 1 percent by volume), with about 0.4 percent NaCl and 0.3 percent penetrant, is allowed to remain in contact with the cloth for 3 - 12 hr. The objective is to provide sufficient contact time to convert by hydrolysis the starch to dextrins which can then be washed out of the cloth. The waste is very strong, often about 50,000 ppm BOD, with a neutral pH. The rinse waters following desizing will vary in strength depending upon the rinsing method. The desize waste is the first real contaminated liquid discharged from the cotton finishing mill. It is usually discharged in the rinse following the grey bins as the cloth proceeds on its path to the scouring operation.

3. Scouring: Scouring removes the natural impurities to the cloth (wax, pectins, alcohols, etc.) as well as the newly acquired impurities (size holdover, dirt, oil, grease, etc.). The fiber in the cloth is rendered whiter and more absorbent for future bleaching and dyeing. In most modern plants, scouring is done in conjunction with desizing rather than in the separate operation described here. Caustic soda (NaOH) and soda ash (NA_2CO_3) are used in most scouring operations, the former in concentrations of 1 - 8 percent of the cloth weight, the latter only 1 - 3 percent OWF. Sodium silicate (Na_2SiO_3) is generally used in smaller doses (0.25 to 1 percent OWF). Pine oil soap to remove wax, and fatty alcohol sulfates to aid in melting, are sometimes used in scouring. Although the fresh scour solution is clear, after scouring under pressure (5 - 15 psi) and at elevated temperature (200°F) for 2 - 12 hr, the scour liquid is an opaque brown. Methods of scouring and dumping of the scour waste vary from mill to mill; however, in all mills the cloth is rinsed completely until no brown color is left in the rinse water. The pH is approximately 12, hydroxide alkalinity usually is very high (10 - 20,000 ppm), and the BOD is high (about 10,000 ppm) in scour liquid waste dumps. Subsequent boil-offs (if necessary) and/or rinses are relatively weaker.

4. Bleaching: Bleaching of cotton cloth may be done with many oxidizing agents, but either hypochlorite or hydrogen peroxide is most common. It may be carried out immediately after the scouring or after mercerizing. It may be done in bins, jigs, or on a continuous basis. In hypochlorite bleaching, the cloth is rinsed first, scoured with acid, H_2SO_4 or HCl, and rinsed again. It is then passed through a hypochlorite solution (about 0.25 to 0.50 percent available chlorine) and squeezed lightly. The time of contact may vary from a few hours to as long as 24 hours at room temperature. The rinses following bleaching are usually neutral in pH, vary in BOD depending upon the impurities in the fiber (such as penetrants) and contain considerable amounts of either free chlorine or peroxide. Continuous bleaching is done with hydrogen peroxide.

5. Mercerizing: Mercerizing, or causticizing, increases the luster, sheen, strength and dye affinity of cotton. It may be done before or after bleaching. The cloth is saturated with cold NaOH (15 - 30 percent) while being stretched on the tenter frame which applies tension to the cloth for a few minutes. The caustic is then thoroughly washed off, sometimes with the aid of an intermediate acid wash. Generally, the caustic soda dragged out by the cloth is recovered and reused for scouring or mercerization. The mercerizing rinse wastes are alkaline, high in inorganic solids and caustic alkalinity, and low in BOD. With the increasing trend toward cotton-polyester blends, much less mercerizing is being done. It is estimated that less than 30 percent of cotton is now mercerized or causticized.

6. Dyeing: There are varied methods of dyeing cotton and many types of dyes are used. Small volumes of cloth are dyed in jigs - which are small, tapered, rhombus-shaped tanks with the large surface area at the top. Larger volumes of cloth are usually dyed in a continuous dyeing range, which consists of a number of boxes through which the cloth passes to be dyed, oxidized, dried and finished. The most important dyes are vat, direct, developed, naphthol, sulfur, aniline black and fiber reactive. Of lesser importance are the mineral and pigment dyes. In vat dyeing, the insoluble dye (1/2 to 4 percent OWF) is made soluble by reduction with 1 - 5 percent sodium hydrosulfite and 1 - 4 percent NaOH. The cloth is impregnated with a vat dye which was reduced to its leuco (colorless) form by passage through the reducing bath. The dye is then re-oxidized back to the insoluble, highly-colored form directly on the goods by 1 percent sodium perborate and steam, or 2 percent sodium dichromate and 2 percent sodium dichromate and 2 percent acetic acid. An acid rinse (usually acetic acid) is used to neutralize the caustic soda. Vat dyes are rapidly replacing sulfur dyes which are similarly applied. Sodium sulfide (1/4 - 8 percent), or hydrosulfite is used to dissolve the sulfur dyes before impregnation on the fiber. A considerable amount of salt (5 - 60 percent) is used to exhaust the dyes. The final color, after thorough impregnation, is developed by oxidizing with sodium perborate, H_2O_2, or $K_2Cr_2O_7$ and $H_2C_2H_3O_2$. A continuous oxidizing process using hydrogen peroxide and producing no residues is also used.

Direct dyes (water soluble) are applied with or without heat directly to cotton with salt (10 - 60 percent) and Na_2CO_3 (1 - 5 percent). Some chemicals, such as acetic acid, copper sulfate, or formaldehyde, may be used occasionally to modify the shade or fastness.

Developed dyes are dyes which result from chemical combinations which take place directly on the fiber. The dye (1/2 - 4 percent) is absorbed and changed to a chemically unstable diazo

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by nitrous acid treatment (40 percent H_2SO_4 plus 8 percent $NaNO_2$). A developer, usually an alkaline solution of naphthol, converts the unstable diazo to a stable azo dyestuff. The dyeing is followed by rinsing.

Naphthol dyeing is developed dyeing in reverse. The cloth is first impregnated with the developer (alkaline solution of naphthol). The dye is then formed on the fiber in the diazotized dye bath.

Aniline black dye is an insoluble pigment produced by the oxidation of aniline. The cloth is passed through a dye bath typically consisting of 90 lb of aniline hydrochloride, 35 lb of sodium chlorate, and 13 lb of $CuSO_4$ in 100 gal of water. After impregnation, the cloth is passed over steam-heated rollers to develop the black pigment. Soaping and washing complete the process. Since the dye bath is costly, it is seldom dumped.

It is imperative to realize that dye wastes are extremely variable in contaminating matter. It is quite usual to discharge about 3000 gal of waste from each bath for each 1000 lb of cloth dyed on jigs. Generally, wasteloads will be less in continuous type dyeing. All of the contaminants in dye waste come from chemicals added to the dye baths.

Colored patterns on cloth are usually printed. In roller printing, the cloth is rolled around a large central cylinder on top of a "dark" cloth used to absorb any printing paste which may seep through. Copper rolls with engraved designs on the circumference of the cylinder are padded with dye paste (from close-by color boxes). These rolls, wiped free of excess paste by a "doctor" blade, pass tightly against the cloth. Dye paste in the engraved depressions is imprinted on the cloth. Steaming or aging treatments finally fix the color prior to washing, rinsing, drying and finishing. Pollution from color shops (where printing is usually done) comes mainly from the washing of tubs, dippers, cloths, drums, and any equipment used to make and carry the printing pastes. Washing the printed cloth also contributes to pollution.

7. Finishing: Finishing imparts a smooth appearance and certain rigidity to the cloth. Starch, dextrin, wax, tallow, oil, clay, talc and other weighting compounds are typical finishing compounds. In recent years, resins, cellulosic solutions, lacquers, sulfonated compounds, and quaternary ammonium salts have been used.

Cotton is often waterproofed, fire-proofed, or mildew-proofed. Starch may be a finishing compound. It is applied by padding a 10 - 30 percent solution to the cloth followed by calendaring and rolling. Other finishing processes, such as leveling off (hot detergent) to produce a uniform appearance, softening (hot soap) to produce a soft feel to the goods, rust stain removal (oxalic acid and sodium acid fluoride) to improve color, and causticizing (NaOH) to remove the outer layer of resin from resin-impregnated linen, are also used sometimes.

B. Significant Pollutants

The significant pollutants produced by cotton finishing processes are:

1. Organic matter. This is usually expressed as BOD or COD. It exerts an oxygen demand on the receiving watercourse and may kill fish, produce taste and odor, form floating scum, and generally be detrimental to beneficial uses of the watercourse.

2. Chemicals. These normally consist of acids, alkalis and inorganic salts. They may kill aquatic life, produce taste and odor, inhibit municipal waste treatment processes, and render the watercourse unfit for agricultural, municipal, and industrial uses.

3. Dyes. These add esthetically objectionable color to the watercourse and in addition contain detrimental chemical constituents.

As shown later in this report, the gross quantities of pollutants produced by this industry run into hundreds of millions of pounds a year.

The major sources of the above pollutants in the cotton finishing plant are the desizing, scouring, and dyeing operations. Wasteloads from other operations are less significant in strength and volume.

In cases where the waste discharge from the plant is a significant portion of the water flowing in the watercourse, thermal pollution will result. A temperature rise in the receiving water may prove detrimental to beneficial uses downstream.

Apparently there is no significant air pollution produced by the cotton textile finishing industry.

C. Process Water Reuse - 1964

We estimate that approximately 16 percent of the industry process water was reused, and 84 percent used only once.

It appears that the percentage of process water reused will increase in the future because newer machinery is often of continuous or counter current design. In addition, because process water is becoming more expensive in many areas, there will be increased use of instrumentation to control processes more precisely.

D. Subprocess Trends

As previously indicated in the description of fundamental manufacturing processes, there are often alternate methods to accomplish a particular operation in the cotton finishing process. Which method is used depends upon such factors as type and color of cotton cloth being finished, type and size of process machinery available, skill of available operating personnel, length of run, and other factors. We have purposely left out the factor of wasteload produced because this does not seem to strongly influence subprocess selection. The plant manager is interested in increasing his production efficiency and product quality and any decrease in wasteload produced by the operation is merely a bonus. There are exceptions of course, but they are isolated.

Table I-1 which projects subprocess trends in the cotton finishing industry is the result of information received from operating plants, textile industry consultants, machinery manufacturers, chemical manufacturers, and a thorough survey of existing literature on the subject. It is intended to show the direction of the industry in 1967 on the basis of techniques now available. Since techniques are used in 1967 that were unheard of in 1950, it is entirely probable that scientific advances will make many of the subprocesses shown obsolete in the next ten years.

TABLE I-1 SUBPROCESS TRENDS

Fundamental Process and Subprocesses	% of Plants Employing Subprocess				
	1950	1963	1967	1972	1982
<u>Desizing</u>					
Enzyme	80	58	15	5	0
High T° Enzyme	20	40	80	85	85
Water (used with CMC)	0	2	5	10	15
<u>Scouring</u>					
Boil-Off	15	15	15	10	5
Kier Boil	70	50	20	5	0
Cont. Scouring	-	20	50	75	90
Wet Out	15	15	15	10	5
<u>Bleaching</u>					
Hypochlorite	50	20	20	10	0
Hydrogen Peroxide	50	80	80	90	100
Continuous	-	50	60	70	80
<u>Mercerizing and Causticizing</u>					
NaOH	40	35	30	25	20
<u>Dyeing</u>					
Vat	90	90	90	90	80
Basic	10	5	0	0	0
Direct	70	75	80	80	90
Naphthol	60	55	50	45	35
Developed	70	50	30	10	0
Sulfur	90	90	90	85	75
Aniline Black	5	5	5	5	5
Fiber Reactive	10	20	40	50	70
<u>Printing</u>					
Roller	95	95	95	90	90
Screen	4	4	4	0	0
Other	1	1	1	10	10

Analysis of Table I-1 in light of wasteload reduction shows that the industry in general is heading in the direction of subprocesses using less process water and producing less wasteload. There is a gradual trend toward the use of CMC sizing compound which reduces the BOD of the desizing operation waste tremendously. The rapid increase in the use of continuous scouring machines will reduce the BOD of the scouring operation considerably. Bleaching is also showing a strong trend toward continuous operation. Mercerizing is no longer used to as large an extent. Continuous dye machines will increase and tend to reduce pollution load produced. The increasing use of fiber reactive dyes will probably tend to increase the pollution load produced by the dyeing operation.

Interestingly, style trends in apparel have an influence upon the wasteload produced by the industry. The type of fabrics and colors popular in a particular style year help determine subprocesses and dyes used.

E. Waste Control Problems

The subprocess wastes which are most likely to cause difficulty in treatment come from desizing and dyeing, due to their high concentrations of BOD chemicals and solids. Dyehouse wastes often cause difficulty because the types and colors of dye solutions from the same plant vary greatly at different times. In addition, dye wastes may be toxic and either acidic or basic. Biological waste treatment processes often do not operate efficiently when subjected to wastewater influents that vary widely in chemical constituents from day to day.

F. Subprocess Technologies

1. Older Technology: This series of subprocesses is typical of the industry in the year 1950.

a. Desizing: Immediately following the singeing process, the cloth is passed through a water box containing a solution of commercial enzyme, although sulfuric acid is occasionally used. In either case, the soaked cloth is stored in grey bins for 3 - 12 hr to allow conversion of the starch to dextrins. Upon completion of this conversion, the solution is rinsed out of the cloth in a running rinse.

b. Scouring: Boil-off by pressure kier boil was the standard method of scouring in the industry in years past. The kier is a steel pressure tank 50 - 60 cu ft in volume into which 2 - 5 tons of cotton cloth are packed, after immersion in a caustic bath (NaOH). The kier liquor, usually a solution containing caustic soda, sodium carbonate, sodium silicate and pine oil soap in variable quantities, is pumped into the kier and boiled under pressures of 5 - 15 psi at temperatures approaching 240°F. During the boil, the kier liquor is pumped from the reservoir at the bottom of the tank to the top to circulate it through the cloth continuously. A thorough scour generally requires 2 - 12 hr of boiling.

After the scouring has been completed, pressure is released and the cloth is cooled and rinsed in the kier.

c. Bleaching: Bleaching is typically done in bins using a hypochlorite or hydrogen peroxide solution with a penetrant to speed the process. H_2O_2 is the most common agent due to the relatively simple procedure involved in its use. Peroxide boiling is done without pressure at a temperature of approximately 190°F with continuous recirculation through the cloth. The time of boil varies from 1½ - 6 hr, depending on the temperature and concentration of the solution. The cloth is then rinsed with warm water in the bin and run through a rope washer to insure removal of the bleach solution.

d. Mercerizing: Cotton is mercerized by treatment with sodium hydroxide in a continuous mercerizer consisting of a train of boxes with squeeze rollers between each box to maintain tension. A tenter frame is used to stretch the cloth while being treated with caustic. Several wash and rinse boxes follow in which water flows countercurrently from the last rinse to the first wash before being discharged.

e. Dyeing: The majority of the plants use all of the seven basic types of dyes to some extent. Direct dyes are used on more than half of all cloth dyed. Sulfur and naphthol dyes have better fastness when compared with direct dyes; however, when fastness is the major consideration, vat dyes are generally used.

f. Printing: The majority of printed cotton is processed on a roller printing machine. The cloth is wrapped around a large padded central cylinder. Several smaller rollers with engraved patterns press tightly against the cloth and transfer the pattern to it. Then the cloth is treated to fix the color and finally washed and rinsed.

g. Final Finishing: Starch base finishing compounds are generally applied to the cloth by padding in a mangle. After impregnation, the cloth is passed through a calendar - a series of heavy rollers - which, in effect, "iron" the cloth.

2. Prevalent Technology: Typical practices followed by the industry in the base year (1963) are generally the same as those outlined under "older technology" except where continuous methods have replaced batch methods, to save time, labor, and process

materials. The following outline describes only those subprocesses which differ significantly from 1950 technology.

a. Scouring and Bleaching: Continuous methods using "J" boxes are used in most plants. This process generally combines scouring and bleaching and may combine the entire series of cotton finishing subprocesses in a single multi-stage continuous train.

Two "J" boxes are used in series. Desized cloth is saturated with a scouring solution similar to kier liquor. The cloth then enters the top of the longer leg (called the Storage Chamber) of the first "J" box and piles up for a detention period of one hour during which it is heated with live steam at 210° - 215°F. After leaving the first "J" box, the cloth is washed and rinsed in either a slack or tight continuous washer. Following the wash, the cloth is saturated in an alkaline hydrogen peroxide solution before entering the second "J" box where it is retained and heated. Temperatures range from 190° - 195°F for goods to be dyed, whereas white goods are heated to a minimum of 212°F. Finally, the cloth is washed, rinsed, and dried using weaker solutions and less time than the first wash.

b. Mercerizing: The prevalent practice is to recover the caustic soda from the first three to five rinse boxes by concentration, evaporation, or dialysis, and reuse it in scouring or mercerizing.

With the increasing trend toward cotton-polyester blends, much less mercerizing is being done. It is estimated that less than 30 percent of cotton is mercerized or causticized at present.

c. Dyeing: The predominant dyes are vat, direct, naphthol, sulphur and fiber reactive. Basic and developed dyes are not used as much as formerly, many more continuous dyeing machines are in use.

3. Newer More Advanced Technology: The series of subprocesses in advanced technology are completely integrated into a single, continuous multi-phase train starting with singeing and ending with mercerizing. The following lists the individual phases through which the cloth passes:

Singer
Quench Tank
Desize Scray (Small "J" Box)
Washer
Caustic Saturator

Caustic "J" Box (Scouring)
Washer
Washer
Peroxide Saturator
Peroxide "J" Box (Bleaching)
Washer
Printing and/or Continuous Dyeing Machine

The singer is basically a gas burner over which the cloth is passed at a rapid rate to remove fuzz. The singed cloth is immediately passed through a quench tank to extinguish sparks and cool the fabric. The quench tank also serves to saturate the cloth with a desizing agent (enzymes). After saturation, the cloth is detained in the desize scray, basically a simple "J" Box, for approximately 30 min at a temperature of 180°F. Desized cloth goes directly to a washing range for light cleansing prior to caustic scouring.

Caustic saturator phase through final washer phase are described in the previous section titled "Prevalent Technology".

In a continuous dyeing machine, the cloth is directed through rollers into a dye bath and a series of washes and rinses. Some machines use standing dye baths while others use recirculating baths. Water usually flows countercurrently through the wash and rinse baths.

4. Plant Classification: Our estimate of the percentage of plants which fall into the three technology categories described in the preceding pages is:

Older: 50 percent Prevalent: 40 percent Newer: 10 percent

The range of plant sizes associated with these three categories is estimated as follows:

	Older	Prevalent	Newer
Smaller, Under 20,000 lb/day	75	23	2
Medium, 20,000-60,000 lb/day	30	60	10
Larger, Over 60,000 lb/day	20	55	25

It must be emphasized that these estimates of the relationship between plant size and state of the art technology used by the plant is intended only to show an industry trend. In general, the larger plants are better able to afford the expensive new machinery and instrumentation associated with advanced technology than are the smaller plants. Also, because the new machinery generally has much higher productivity than the old machinery, the new plants being built tend to be high production plants and to be classified by the industry as large plants.

It should also be noted that when we speak of plant age we mean the production machinery and techniques used by that plant and not the age of the building shell. There are many instances of very modern production lines installed in ancient buildings.

When one attempts to classify the textile finishing industry into technological categories by plant percentages it can present a false picture. The fact is that approximately twenty very large plants finish over half of the cotton cloth production. On the other end of the scale are hundreds of small dye and finish plants which are generally located near the apparel cutting houses. These small plants have a limited number of old machines and operate profitably on low volume special lots. These small plants are classified technologically old but in the national picture contribute a relatively small percentage of the pollution load. The large plants, on the other hand, are high production relatively efficient operations. They would be classified technologically prevalent or newer but because of their high production volume they generate a relatively high percentage of the pollution load.

II. GROSS WASTE QUANTITIES

A. Daily Waste Quantities

As previously indicated in section I.D., daily wasteloads and volumes per unit of product produced by the average cotton textile finishing plant have decreased since 1950 and are expected to continue to decrease in the future. In the following Table II-1, the extent of the decrease is tabulated for a theoretical plant producing 20,000 lb of cloth per day. We arbitrarily have this fictitious plant using a completely old technology (year 1950), completely prevalent technology (year 1963), and a completely newer technology (year 1967). The theoretical daily average wasteloads and volumes are tabulated for each technology. The possible ranges in wasteload production are extremely wide and the values shown are an average only. A specific plant on a particular day could deviate widely from the figures shown.

TABLE II-1 DAILY WASTE QUANTITIES

Subprocess of Older Technology	Approx. % of Cloth Treated	Wasteload-lb/day for Average Size Plant Producing 20,000 lb/day			Wastewater Volume (mgd)
		BOD	SS	TDS	
Desizing	95	1,270	665	1,100	.06
Scouring	100	1,060	500	1,300	.10
Bleaching	100	150	100	800	.10
Mercerizing	40	150	40	700	.30
Dyeing	50	620	250	800	.40
Printing	14	150	45	200	.04
TOTAL		3,400	1,600	4,900	1.00
Subprocesses of Prevalent Technology					
Desizing	95	1,100	570	1,000	.05
Scouring	100	1,050	431	1,300	.09
Bleaching	100	150	100	700	.09
Mercerizing	35	50	15	200	.08
Dyeing	50	600	250	700	.40
Printing	14	150	34	200	.04
TOTAL		3,100	1,400	4,100	0.76
Subprocesses of Newer Technology					
Desizing	95	1,000	500	950	.05
Scouring	100	950	400	1,250	.08
Bleaching	100	100	100	600	.08
Mercerizing	30	35	10	130	.06
Dyeing	50	565	200	620	.38
Printing	14	150	30	200	.04
TOTAL		2,800	1,240	3,750	0.69

B. Wasteload Production Rates

Following is the average wasteload production per 1000 lb of cloth produced, classified by state of technology.

WASTELOAD PRODUCTION RATES

Technology	BOD (lb)	SS (lb)	TDS (lb)	Volume (MG)
Older	170	80	245	.05
Prevalent	155	70	205	.038
Newer	140	62	187	.035

C. Total Wasteload

Research in U.S. Department of Commerce statistics reveals the following data for 1963:

Finished cotton fabric

Whites:	3,450 million yd	Extrapolated from percentages shown in U.S. current industrial reports.
Colored:	3,510 million yd	
Prints:	1,100 million yd	
Total:	8,060 million yd	

Converting to Pounds on Basis of 4 yd per lb:

Whites:	862 million lb =	43 percent
Colored:	878 million lb =	43 percent
Prints:	275 million lb =	14 percent
Total:	2,015 million lb =	100 percent

We assume from these figures and previous discussions that 95 percent of the cloth will be desized, 100 percent will be scoured, 100 percent will be bleached, 30 percent will be mercerized, 50 percent will be dyed (assume half of printed is dyed first), and 14 percent will be printed.

Based upon the foregoing data and a mixture of plant technologies of 50 percent older and 50 percent prevalent in 1963 we project the following gross wasteload quantities produced by the cotton finishing industry in 1963.

BOD...........528 million lb
SS............166 million lb
TDS...........498 million lb
Volume........97.6 billion gal

D. Gross Wasteload Projections

On the basis of the technological advances anticipated in the cotton textile finishing industry and the projected growth of the industry, we have projected gross wasteloads produced through 1982.

Gross Wasteloads and Wastewater Volume Projected on Basis of Product Values Supplied by FWPCA and Predicted Subprocess Mix for Year:

Year	Value Added (Million $)	BOD (Million Lb)	SS (Million Lb)	TDS (Million Lb)	Volume (Billion Gal)
1963	347.5	528	166	498	97.6
1967	383.0	534	168	500	97.9
1968	386.0	534	167	499	97.9
1969	391.0	531	166	498	99
1970	395.0	529	165	497	99
1971	400.0	528	164	496	100.1
1972	405.0	526	163	495	100.1
1977	437.0	516	160	494	102.3
1982	469.0	502	154	483	105.6

The gross pollution load produced by the industry will decrease slowly in the coming years in spite of a gradual increase in production. The industry generally purchased new machinery during 1965 and 1966 at an accelerated rate, and this trend toward increased capital expenditure is expected to continue. As previously discussed, the new machinery tends to produce less pollution per unit of cloth production than the older machinery. In addition, the trend in process modifications, new chemicals, and better housekeeping are all favorable toward reducing pollution.

E. Seasonal Variations:

Since cotton is easily stored and non-perishable, seasonal variations are primarily the result of variable demand for cloth by the industries using textiles to make apparel, blankets, etc., there are no significant variations in textile finishing waste volume over the year.

III. WASTE REDUCTION PRACTICES

A. Processing Practices

Table III-1, outlines the relative pollution reduction potentials of the various alternative subprocesses used in the cotton industry. The "older" technological method in each case is used as the basis for comparison. The values shown are generally the highest reported reductions for a particular alternate subprocess.

TABLE III-1 POLLUTION REDUCTION BY ALTERNATE SUBPROCESSES

Fundamental Processes and Subprocess	BOD Lb/1000 Lb	Process Reduction Efficiency (%)	Remarks
Desizing:			
1. Enzymes	67	0	BOD Reduction due mainly to use of CMC/Starch Formulation in weaving mill.
2. Water CMC/ Starch Formulation	20	70	
Scouring:			
1. Boil-off	53	0	NaOH used in both cases but cont. process allows use of less solution.
2. Contin. Scour	42	21	
Bleaching:			
1. Bins	4	0	H_2O_2 used predominantly
2. Continuous	3	25	
Mercerizing and Causticizing			
1. Continuous	15	0	
2. Cont. in Recovery of NaOH	6	60	
Dyeing:			
1. Batch	10 - 60	0	Synthetic detergents used in wash after dyeing.
2. Continuous	5 - 32	50	
Syn. Det.	5 - 8	80	
Printing:			
1. Roller w/soap wash	43	0	In Prevalent tech., both soap and synthetic detergents are used.
2. Roller with Syndet wash	19	53	
3. Soap & Syndet	30	30	

Table III-1 indicates the potential pollution reduction by substitution of alternate manufacturing subprocesses. In most cases, the reduction is associated with high speed continuous machines or substitution of alternate chemicals. The economic feasibility of purchasing new machinery or substituting alternate chemicals is, of course, an individual decision for each finishing plant. It is anticipated that pollution reduction will become an increasingly important factor in future management decisions.

B. Treatment Practices

1. Removal Efficiencies

Table III-2 shows removal efficiencies of various waste treatment methods. Based on a typical waste generated by prevalent plants in the base year 1963, the removal efficiencies are expressed in terms of percentage of gross wasteload removed by the removal process.

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TABLE III-2 TREATMENT REMOVAL EFFICIENCIES

Removal Method	Removal Efficiency (Percent)		
	BOD	SS	TDS
Screening	0-5	5-20	0
Plain Sedimentation	5-15	15-60	0
Chemical Precipitation	25-60	30-90	0-50
Trickling Filter	40-85	80-90	0-30
Activated Sludge	70-95	85-95	0-40
Lagoon	30-80	30-80	0-40
Aerated Lagoon	50-95	50-95	0-40

In Table III-2 it is assumed that the auxiliary units normally associated with the removal method are included. For example, the removal efficiencies for the activated sludge process and trickling filter process assume that the primary and secondary sedimentation tanks are included in the process.

2. Rates of Adoption

The rate of adoption of waste treatment practices in the textile finishing industry has paralleled, to some extent, the trends in the municipal sewage treatment area. As technology has advanced, the attainable standards of pollution reduction have increased also.

Work in recent years by Souther and others indicates clearly that the activated sludge process with modifications (primarily extended aeration time and influent pH adjustment) will consistently produce BOD reductions on the order of 90 percent. As the discharge requirements imposed upon the textile finishing plants are upgraded, it is probable that future waste treatment facilities will be predominately of the activated sludge type.

Generally, the textile cotton finishing waste treatment process should begin with a holding and equalization basin. This will level out the volume of flow and pollution strength to the following treatment units. A reasonably uniform waste can be treated biologically with much greater success than can a widely fluctuating waste.

Since the waste is relatively low in suspended solids and high in dissolved solids, it is often feasible to skip the primary settling step and begin directly with the aeration tank. In some cases where the pH is too high, toxic elements or some other factors inhibiting to the biological treatment may be present, making chemical pretreatment necessary prior to the aeration tank.

The activated sludge process for cotton textile waste is often modified by increasing the aeration time and carrying a higher concentration of mixed liquor suspended solids in the aeration tank. With careful operation this process will produce excellent reduction of BOD and suspended solids. If some domestic sewage is available to mix with the textile waste, the efficiency of the plant is generally increased.

To lower construction costs, an aerated lagoon is sometimes substituted for the activated sludge process. Properly operated, it is capable of closely approaching the pollution removal efficiency of the conventional activated sludge process.

The trickling filter biological treatment is widely installed, but the trend is away from its use in recent years. It cannot reach the removal efficiencies of the activated sludge process and generally lacks operational flexibility.

Where cheap land is available, an inexpensive tertiary treatment is simply storage in a pond of the secondary effluent from the biological treatment process. Simple storage will often reduce the effluent pollution load an additional 50 percent, for example, increasing removal from 90 to 95 percent.

In order to project percent reduction of waste in treatment facilities in Part III.E., it is necessary to predict rate of increase in percentage of waste volume treated and average reduction of pollution in treatment. These predictions follow:

Year	Percent Waste Treated Municipally	Average Reduction (Percent)	Percent Waste Treated By Industry	Average Reduction (Percent)	Total Reduction (Percent)
1967	35	85	25	80	49.5
1968	36	85	27	80	52.0
1969	37	85	29	80	54.5
1970	38	86	31	80	57.5
1971	39	86	33	80	60.0
1972	40	86	35	80	62.5
1977	43	87	40	80	69.5
1982	45	87	45	80	75.0

This predicted rapid increase in treatment is based on continued strong pressure by regulatory agencies upon industry to reduce pollution discharged, continued large capital investment to build new plants and phase out old ones, continued tendency to locate new plants where a municipal sewer is available for waste discharge, and advancing technology in waste treatment processes.

3. Discharge to Municipal Sewers

Percentage of wastes discharged to municipal sewers is estimated for the past and present, and projected to the future as shown below.

Year	1950	1963	1967	1972
Percent	20	30	35	40

Many municipal waste treatment methods will be susceptible to shock loads from the mills and, therefore, pretreatment should include flow regulation and equalization holding procedures to insure waste uniformity. In a large municipality the mill waste would be diluted sufficiently before reaching the treatment facility and would not harm the operation. Even so, most large municipalities require finishing plants to provide screening and constant discharge holding basins. Normally, a cotton finishing plant waste is easily handled by conventional municipal treatment methods.

C. By-Product Utilization

There is no significant by-product use of wastes in the cotton textile finishing industry. Various researchers have attempted to develop economically feasible methods for recovery of the expensive dyeing compounds, but were unsuccessful. We cannot foresee future by-product use on any significant scale.

D. Net Waste Quantities - 1963

The net waste quantities equal the gross quantities produced less the pollution removed by industry-operated and municipally-operated waste treatment facilities. For the base year, we estimate 30 percent of the waste volume was treated by municipal facilities with an average pollution reduction of 85 percent. We further estimate that 20 percent of the waste volume was treated by industry-operated facilities, with an average pollution reduction of 80 percent. On this basis, net pollution reaching water courses in 1963 from the cotton textile finishing industry approximated:

BOD.............................. 309 million lb
SS................................ 96.8 million lb
Total Dissolved Solids............. 423 million lb

E. Projected Net Wasteloads

It is expected that the quantity of pollution load reaching the nation's watercourses from the cotton textile finishing industry will decrease greatly in the future. This will be the result of reduced gross pollution produced, a larger percentage of waste treated, and increased removal efficiencies of waste treatment methods. Table III-3 projects net wasteloads through the year 1982.

TABLE III-3 PROJECTED NET WASTELOADS

Year	Waste	Gross Produced Waste Million Lb	Percent Removed	New Waste Quantity Discharged Million Lb
1963	BOD	528	41	309
	SS	166	41	96
	TDS	498	15	423
1967	BOD	535	49	271
	SS	168	49	84
	TDS	500	16	420
1968	BOD	534	52	255
	SS	167	52	80
	TDS	499	16	419
1969	BOD	531	54	242
	SS	166	54	75
	TDS	498	16	418
1970	BOD	529	57	224
	SS	165	57	70
	TDS	497	17	412
1971	BOD	528	60	221
	SS	164	60	66
	TDS	496	12	411
1972	BOD	526	62	197
	SS	163	62	60
	TDS	495	18	406
1977	BOD	516	69	157
	SS	160	69	48
	TDS	494	20	391
1982	BOD	502	75	125
	SS	154	75	38
	TDS	483	22	377

Table III-3 reflects the anticipated increased emphasis on clearing up rivers and streams throughout the country. Considering the federal and state pollution abatement programs now being effected, it is probable that within the next 15 years no textile finishing plant will be allowed to discharge untreated waste into a waterway. In addition, it is probable that the pollution reduction efficiency required of the treatment will be much higher than now required.

The TDS (dissolved solids) will not be significantly reduced because most conventional waste treatment methods have little effect on this waste constituent. Certain advanced tertiary treatment methods are being developed to remove dissolved inorganic solids; however, it appears doubtful that there will be significant use of these methods before 1982.

IV. COST INFORMATION

A. Existing Facilities Costs

We estimate that the replacement value of total cotton textile finishing industry owned and operated waste reduction facilities in 1966 was $9.5 million. We estimate that the annual operating and maintenance cost of cotton textile finishing industry owned and operated waste reduction facilities in 1966 was $1.4 million.

It must be noted that the above values are for industry owned and operated plants only. We estimate that in 1966 approximately 34 percent of the waste was discharged into and treated by municipal systems. Since industry pays taxes and surcharges to support these facilities, the true industry cost exceeds the foregoing amounts.

We estimate that the replacement value of that portion of municipal facilities construction attributable to this industry waste is $15 million. On the same basis, the annual operating and maintenance cost is estimated at $2.4 million.

Totals: Replacement Value - $24.5 million in 1966.
Operating & Maintenance - $3.7 million in 1966.

B. Processing and Treatment Costs

This portion of the survey analyzes costs involved in subprocesses and end of line treatment. These are further broken down into size of plant and state of technology; i.e., older, prevalent and newer. Because of the wide ranges in the information feedback from the textile industry, we have inserted ranges in the following tables. In addition, we have added a table which gives cost data on the entire cotton textile finishing industry and relates costs of waste treatment to cost of production. We believe this latter table gives a much more accurate picture of the present industry cost situation than do the tables preceding it.

It should be noted that new machinery for subprocesses is purchased by the industry on the basis of increasing production efficiency and product quality - not on the basis of decreasing the pollution load produced by the subprocess. Any such decrease is merely a bonus in most cases.

It should also be noted that the end of the line waste treatment has virtually no relationship to the technology of the process that created the waste or the size of the finishing plant; i.e., an older technology plant may have an extremely efficient, modern, waste treatment facility, and a modern, efficient finishing plant may have no waste treatment facility at all. With few exceptions, the end of the line treatment selected is primarily on the basis of requirements imposed by regulating agencies responsible for the water courses being affected.

It should also be noted that we are required to estimate costs for plants incorporating pure states of technology; i.e., completely old, completely prevalent, completely advanced. Few such plants exist. Most plants are mixtures of varied subprocess technologies, since they have been modernized in stages over a relatively long period of time.

Several definitions are necessary to understand the following tables:

Old Technology - That technology new in 1950.
Prevalent Technology - That technology new in 1963.
Advanced Technology - That technology new in 1967.
Small Plant - Produces less than 5000 lb cloth/day.
Medium Plant - Produces from 5000 to 40,000 lb cloth/day.
Large Plant - Produces over 40,000 lb cloth/day.
Capital Cost - Equivalent 1966 cost.
Annual Operating and Maintenance Costs - Equivalent 1966 cost.
Economic Life - The economic life is the length of time the machine or structure can be expected to compete with advancing technology. It is an estimate of the length of time required for economic obsolescence. This will vary greatly in different industries depending upon the nature of the product, dynamics of industry growth, etc.

TABLE IV-1 COTTON FINISHING - SMALL PLANT (15,000 lb/day)
OLDER TECHNOLOGY (1950)

Item	Capital Costs	Annual Operating & Maintenance Costs	Economic Life
	($1000)	($1000)	(Years)
Alternative Subprocesses			
Enzyme Desizing	15 - 20	10 - 15	10
Batch Scour	25 - 35	15 - 25	10
Batch Bleaching	40 - 60	30 - 35	10
Causticizing	15 - 20	10 - 20	10
Batch Dyeing	80 - 110	75 - 105	10
Printing	80 - 110	75 - 105	10
Final Finishing	40 - 60	25 - 35	10
Rest of Plant	205 - 285	90 - 140	15
Total	500 - 700	330 - 480	
End of Line Treatment			
Screening	2.8 - 14	0.8 - 1.4	10
Sedimentation	6.6 - 18	1.0 - 2.8	10
Chemical Precipitation	14 - 30	7.2 - 15	10
Trickling Filter	26 - 58	3.6 - 8.8	10
Activated Sludge	32 - 88	5.0 - 15	10
Lagoon	2.2 - 7	0.4 - 0.8	10
Aerated Lagoon	7.2 - 22	2.2 - 6.6	10

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-2 COTTON FINISHING - MEDIUM PLANT (50,000 lb/day)
OLDER TECHNOLOGY (1950)

Item	Capital Costs	Annual Operating & Maintenance Costs	Economic Life
	($1000)	($1000)	(Years)
Alternative Subprocesses			
Enzyme Desizing	35 - 50	30 - 45	8
Scour	60 - 90	45 - 70	8
H_2O_2 Bleaching	95 - 150	90 - 110	8
Mercerizing	35 - 50	40 - 65	8
Dyeing	195 - 265	225 - 320	8
Printing	195 - 265	225 - 320	8
Final Finishing	95 - 150	70 - 110	8
Rest of Plant	510 - 690	275 - 430	15
Total	1220 - 1710	1000 - 1470	
End of Line Treatment			
Screening	7 - 35	2.2 - 5	10
Plain Sedimentation	15 - 44	3.4 - 5	10
Chemical Precipitation	35 - 69	24 - 46	10
Trickling Filter	62 - 140	12 - 28	10
Activated Sludge	78 - 209	16 - 46	10
Lagoon	5 - 18	1.2 - 2.4	10
Aerated Lagoon	18 - 52	7.0 - 20	10

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-3 COTTON FINISHING - LARGE PLANT (100,000 lb/day)
OLDER TECHNOLOGY (1950)

Item	Capital Costs	Annual Operating & Maintenance Costs	Economic Life
	($1000)	($1000)	(Years)
Alternative Subprocesses			
Enzyme Desizing	55 - 75	45 - 75	6
Scour	95 - 138	70 - 115	6
H_2O_2 Bleaching	155 - 235	140 - 170	6
Causticizing	55 - 75	60 - 85	6
Batch Dyeing	310 - 430	360 - 505	6
Printing	310 - 430	360 - 505	6
Final Finishing	160 - 234	115 - 170	6
Rest of Plant	810 - 1100	430 - 675	15
Total	1950 - 2720	1580 - 2300	
End of Line Treatment			
Screening	10 - 49	3.2 - 7	10
Plain Sedimentation	22 - 62	4.8 - 13	10
Chemical Precipitation	49 - 99	32 - 65	10
Trickling Filter	87 - 20	16 - 39	10
Activated Sludge	110 - 296	22 - 65	10
Lagoon	7 - 25	1.7 - 2	10
Aerated Lagoon	25 - 74	9.7 - 29	10

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-4 COTTON FINISHING - SMALL PLANT (15,000 lb/day)
PREVALENT TECHNOLOGY (1963)

Item	Capital Costs	Annual Operating & Maintenance Costs	Economic Life
	($1000)	($1000)	(Years)
Alternative Subprocesses			
Enzyme Desizing	20 - 25	10 - 15	10
Batch Sour	30 - 25	10 - 20	10
Batch Bleaching	50 - 80	25 - 35	10
Batch Dyeing	105 - 145	65 - 90	10
Printing	105 - 145	65 - 90	10
Final Finishing	50 - 80	20 - 35	10
Rest of Plant	270 - 370	80 - 125	15
Total	630 - 870	280 - 410	
End of Line Treatment			
Screening	2.4 - 12	0.7 - 1.4	10
Plain Sedimentation	5.4 - 15	1.2 - 2.9	10
Chemical Precipitation	12 - 24	7 - 14	10
Trickling Filter	20 - 48	3.6 - 8.6	10
Activated Sludge	26 - 72	5 - 14	10
Lagoon	2 - 6	0.2 - 0.7	10
Aerated Lagoon	6 - 18	2.4 - 6.5	10

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-5 COTTON FINISHING - MEDIUM PLANT (50,000 lb/day)
PREVALENT TECHNOLOGY (1963)

Item	Capital Costs	Annual Operating & Maintenance Costs	Economic Life
	($1000)	($1000)	(Years)
Alternative Subprocesses			
Enzyme Desizing	45 - 60	20 - 30	8
Continuous Scour	75 - 110	30 - 50	8
Continous H_2O_2 Bleaching	130 - 190	65 - 75	8
Dyeing	255 - 350	160 - 225	8
Printing	255 - 350	160 - 225	8
Final Finishing	130 - 190	75 - 115	8
Rest of Plant	660 - 900	280 - 440	15
Total	1550 - 2150	790 -1160	
End of Line Treatment			
Screening	6 - 30	2 - 5	10
Plain Sedimentation	14 - 38	3 - 8	10
Chemical Precipitation	30 - 60	20 - 40	10
Trickling Filter	53 - 120	10 - 24	10
Activated Sludge	68 - 180	14 - 40	10
Lagoon	5 - 15	1 - 2	10
Aerated Lagoon	15 - 45	6 - 18	10

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-6 COTTON FINISHING - LARGE PLANT
(100,000 lb/day) - PREVALENT TECHNOLOGY (1963)

Item	Capital Costs	Annual Operating & Maintenance Costs	Economic Life
	($1000)	($1000)	(Years)
Alternative Subprocesses			
Enzyme Desizing	70 - 100	40 - 65	6
Continuous Scour	120 - 180	65 - 105	6
Continuous H_2O_2 Bleaching	205 - 305	130 - 155	6
Dyeing	405 - 560	325 - 455	6
Printing	405 - 560	325 - 455	6
Final Finishing	205 - 305	100 - 155	6
Rest of Plant	1050 - 1430	385 - 610	15
Total	2460 - 3440	1370 - 2000	
End of Line Treatment			
Screening	12 - 61	3 - 7	10
Plain Sedimentation	27 - 77	5. - 14	10
Chemical Precipitation	61 - 122	36 - 72	10
Trickling Filter	107 - 245	18 - 44	10
Activated Sludge	138 - 367	26 - 72	10
Lagoon	9 - 31	2 - 4	10
Aerated Lagoon	31 - 92	11 - 32	10

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-7 COTTON FINISHING - SMALL PLANT (15,000 lb/day)
NEWER TECHNOLOGY (1967)

Item	Capital Costs	Annual Operating & Maintenance Costs	Economic Life
	($1000)	($1000)	(Years)
Alternative Subprocesses			
Desizing	20 - 30	10 - 15	10
Batch Scour	35 - 50	15 - 20	10
Bleaching	55 - 85	25 - 40	10
Batch Dyeing	115 - 145	65 - 90	10
Printing	115 - 145	65 - 90	10
Final Finishing	55 - 85	20 - 35	10
Rest of Plant	295 - 400	80 - 120	15
Total	690 - 940	280 - 410	
End of Line Treatment			
Screening	2.4 - 12	0.6 - 1.2	10
Plain Sedimentation	5.4 - 15	1 - 2.4	10
Chemical Precipitation	12 - 24	6 - 12	10
Trickling Filter	20 - 48	3 - 7.2	10
Activated Sludge	26 - 72	4.2 - 12	10
Lagoon	2 - 6	0.2 - 0.6	10
Aerated Lagoon	6 - 18	2 - 5.4	10

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-8 COTTON FINISHING - MEDIUM PLANT (50,000 lb/day)
NEWER TECHNOLOGY (1967)

Item	Capital Costs	Annual Operating & Maintenance Costs	Economic Life
	($1000)	($1000)	(Years)
Alternative Subprocesses			
Desizing	50 - 70	25 - 35	8
Scouring	80 - 125	40 - 65	8
H_2O_2 Bleaching	135 - 205	80 - 95	8
Dyeing	275 - 375	95 - 280	8
Printing	275 - 375	95 - 280	8
Final Finishing	135 - 205	65 - 95	8
Rest of Plant	710 - 970	240 - 370	15
Total	1660 - 2330	640 - 1220	
End of Line Treatment			
Screening	6 - 30	2 - 4	10
Plain Sedimentation	14 - 38	3 - 8	10
Chemical Precipitation	30 - 60	20 - 40	10
Trickling Filter	53 - 120	10 - 24	10
Activated Sludge	68 - 180	14 - 40	10
Lagoon	5 - 15	1 - 2	10
Aerated Lagoon	15 - 45	6 - 18	10

Special Notes:
1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-9 COTTON FINISHING - LARGE PLANT (100,000 lb/day) NEWER TECHNOLOGY (1967)

Item	Capital Costs	Annual Operating & Maintenance Costs	Economic Life
	($1000)	($1000)	(Years)
Alternative Subprocesses			
Desizing	80 - 110	40 - 65	6
Scouring	130 - 190	60 - 100	6
H_2O_2 Bleaching	210 - 320	125 - 150	6
Dyeing	435 - 600	315 - 435	6
Printing	435 - 600	315 - 435	6
Final Finishing	210 - 320	100 - 150	6
Rest of Plant	1140 - 1550	375 - 585	15
Total	2640 - 3690	1330 -1920	
End of Line Treatment			
Screening	12 - 58	3 - 7	10
Plain Sedimentation	26 - 73	5 - 14	10
Chemical Precipitation	58 - 116	34 - 68	10
Trickling Filter	102 - 231	17 - 40	10
Activated Sludge	129 - 347	24 - 68	10
Lagoon	9 - 29	2 - 4	10
Aerated Lagoon	3 - 9	10 - 30	10

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

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TABLE IV-10

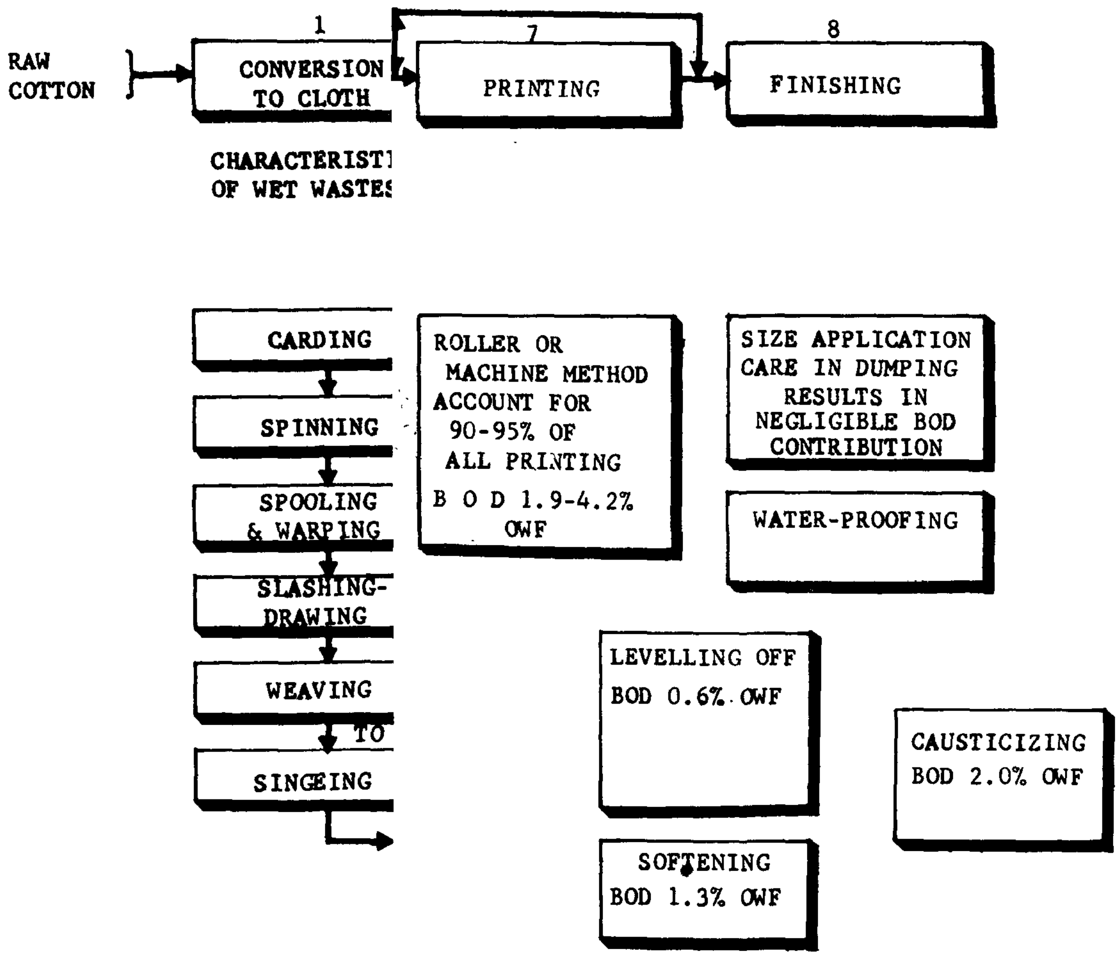
SUMMARY OF PRODUCTION AND WASTE TREATMENT COSTS

Cotton Textile Finishing

Item	Quantity
Total Production	2015 Million lb.
Total Value added in manufacturer[1]	328 Million $
Average unit value added in manufacturer	0.16 $/lb
Estimated replacement value of waste reduction facilities[2]	24.5 Million $
Annual amortized cost of facilities at 7% and 10 yr life[2]	3.5 Million $
Estimated annual waste reduction operating and maintenance cost[2]	2.2 Million $
Average industry cost of waste treatment per unit of production	.003 $/lb
Total waste reduction costs as percent of total production cost	1.7 Percent

1 From the Business and Defense Services Administration, U. S. Department of Commerce, 1967.

2 Estimated replacement value, estimated amortization, and estimated annual operating costs include an estimate of the cost of municipal facilities attributable to this industry's wastes.



Prepared for F.W.P.C.A.

I.W.P. NO. 4
COTTON TEXTILE FINISHING
PROCESS FLOW CHART - SIC 2261

PLATE 1

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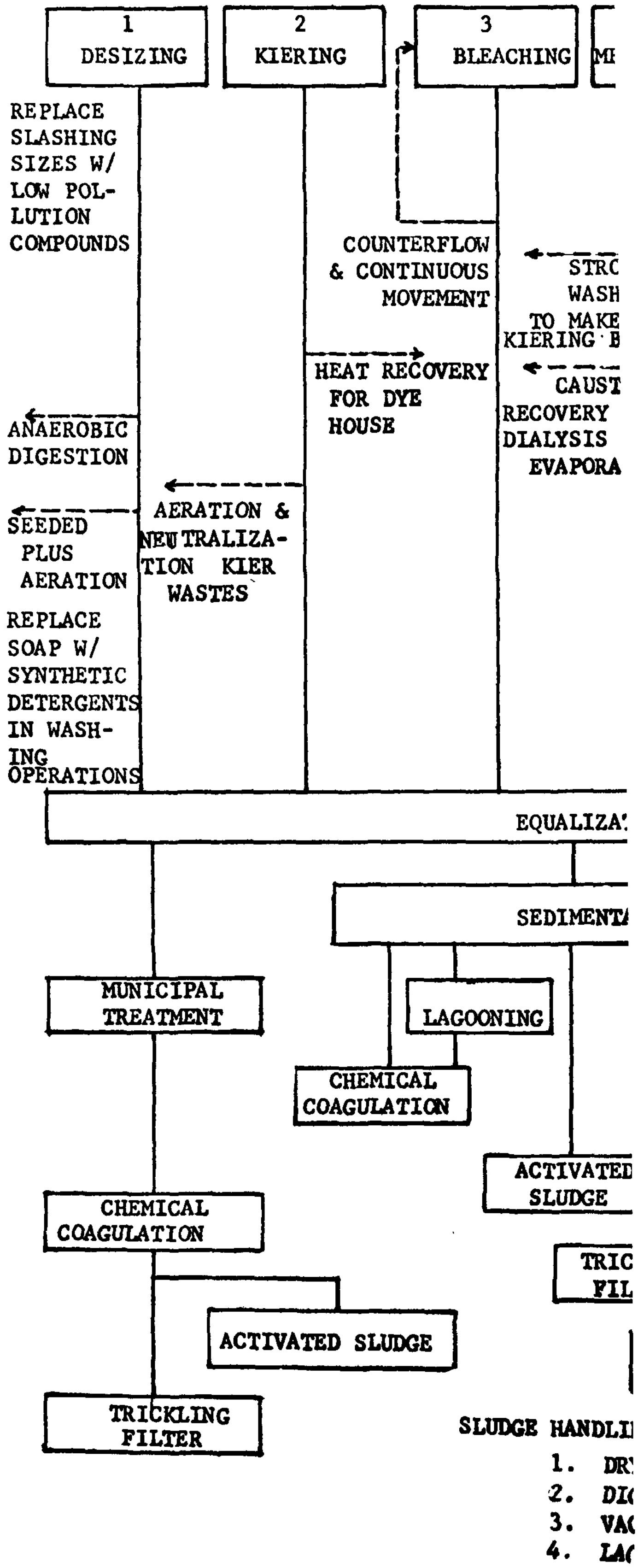

Prepared for F.W.P.C.A.

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COTTON TEXTILE FINISHING

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Industrial Waste Profile

Synthetic Textile Finishing - SIC 2262

U. S. Department of the Interior
Federal Water Pollution Control Administration
I.W.P. No. 4 - Synthetic Textile Finishing

INDUSTRIAL WASTE PROFILE STUDIES
TEXTILE PRODUCTS

SIC 2262, SYNTHETIC TEXTILE FINISHING

INTRODUCTION

Synthetic fibers, namely those fibers which are man-made and not found in nature, fall into two main groups: those produced from cellulose and those produced synthetically from organic materials. The cellulosic fibers are principally rayon and acetate. The organic fibers are principally acrylics, polyesters, and nylon. The organic synthetic fiber industry is the most rapidly growing segment of the textile industry and is continually creating new and varied fibers to add to the already large number of synthetic fibers now on the market.

I. PROCESSES AND WASTES

A. Fundamental Processes

Process Description: There are generally three key waste-producing steps in the series of finishing processes for synthetic textiles[1].

1. Scouring
2. Dyeing or Bleaching
3. Special finishing (optional)

There are two main variations of the basic finishing process.

1. Rayon and acetate finishing usually includes:
    a. Chemical preparation
    b. Scouring and dyeing
    c. Salt bath (rayon only)
    d. Special finishing (optional)

2. Nylon, acrylic and polyester usually includes:
    a. Scouring
    b. Dyeing or bleaching
    c. Scouring (acrylic and polyester only)
    d. Special finishing (optional)

Scouring: Because chemical impurities are virtually absent in synthetic textiles, only relatively light scouring is needed to prepare them for dyeing. Scour baths usually contain weak alkalis, anti-static agents, lubricants, and soap or detergents, totaling approximately 5 percent OWF (Of weight of Fiber).

When cloth is received at the finishing mill, it contains sizing which was applied to improve weaving characteristics. These sizes are removed in the scour, thereby contributing to the pollution load. Because of the relatively low moisture regain of most synthetic fibers, the amount of size used and removed is very small 1/2 to 3 percent OWF.

There are two principal scouring processes. Acetate may be scoured and dyed in one bath; rayon, nylon, acrylic, and polyester are scoured independently of, and preceding, the dyeing operation.

Rayon, nylon, polyester, and acrylic receive a scour of weak alkalis (such as tetrasodium pyrophosphate), anti-static lubricants (such as alcohol phosphates), and soap. This operation may be done by a variety of equipment including the following:

- Beam dyeing equipment
- Rope soaper
- Jig scour
- Beck scour
- Drum or paddle scour

After scouring, the material is rinsed to remove excess material in preparation for the dye bath. Nylon scour and rinse wastes have an average BOD of 1360 ppm of which 40 to 50 percent is anti-static lubricants, 40 to 50 percent is soap and 10 to 20 percent is fatty esters. Acrylic scour and rinse wastes average 2190 ppm BOD (6.6 percent OWF) of which 30 to 50 percent is due to anti-static lubricants and 50 to 70 percent is due to soap. The pH averages 8.8.

Scour and Dye: Rayon and acetate may be dyed and scoured concurrently. Scour materials are oils and synthetic detergents. Most conventional dyes may be used with rayon; acetate generally requires special dyes. Dyeing is often followed by one rinse for rayon and two rinses for acetate. Scour and dye wastes usually contain 5 to 6 lb BOD/1000 lb finished textile.

The pH is near neutral, but color is a problem with these wastes.

Scour and Bleach: Rayon and acetate cloths require little bleaching because of their inherent whiteness. Sodium chlorite is the usual bleaching agent. Hydrogen peroxide may also be used at the rate of 0.15 lb/1000 lb cloth. Chlorine may be used to remove soil from acetate. The chlorine bath should be cold, slightly acidic, and not over 1000 ppm strength. These weak bleaches are sufficient because the textiles contain very little impurity. Scour and bleach wastes may be either high or low pH.

Dyeing: Dyeing is the most varied and difficult part of the finishing-process. An important variable is the ability of the fiber to absorb water. Rayon is hydrophilic, that is, it absorbs moisture readily. Acetate and nylon absorb 4 to 6 percent moisture after drying and are called "intermediate" fibers. Acrylic and polyester are hydrophobic, resisting water absorption almost completely. Acrylic and polyester present special difficulties. They commonly require the use of carriers or high temperatures and pressure to swell and soften the fibers enough for dye to penetrate. Dyeing of acrylic and polyester is the most difficult aspect of synthetic textile finishing.

Nylon and acetate are dyed by conventional dyeing methods, such as acid, direct, vat or dispersed. The dispersed method is normally used to get black and some navy blues.

The following is the normal procedure in dispersed-developed dyeing of acetate:

Dye bath
Na_2NO_2+ HCl bath
Rinse
Development bath
Rinse

Waste from this process contains from 300 to 456 ppm BOD. Acid, chrome or dispersed-developed dyes are used on nylon.

There are several alternate methods of dyeing acrylics[3]. The two most prevalent methods are acid dye with cationic assistant and cuprous ion dye with phenol and aromatic amines. The cuprous ion method also uses glyoxol, hydroxyammonium sulfate, sodium bisulfate, and formic acid. Wastes from the cuprous ion method average 0.5 percent BOD OWF by test, but should be 5.7 percent based on chemical analysis. This discrepancy illustrates the inhibiting effect of phenol on biological action.

A group of carriers, used mostly in the dispersed and acid dyeing of polyesters[4], produce varying estimated dye waste BOD loadings as follows:

Carrier	Waste BOD
Chlorinated Benzenes	As low as 480 ppm
Ortho-phenyl-phenol	6,060 ppm
Phenylmethylcarbinol	19,000 ppm
Benzoic or Salicylic Acid	25,000 ppm

Recovery of these carriers is an important part of synthetic textile waste treatment. Chlorinated benzenes are extremely toxic to humans and require special vented equipment. They have the advantage of low BOD's.

High temperature and pressure are sometimes used with dispersed and acid dyes on acrylic and polyester. Temperatures of 212° to 250°F eliminate the need for carriers by softening and swelling the fibers so dyes can penetrate. This method produces high temperature wastes with no BOD.

Thermosol padding is an alternate means of dyeing which produces only occasional batches of soap and rinse water. This method involves oven drying at 175° to 200°C and is a potential source of air pollution.

Carrier dyeing may be a potential source of process problems, such as color inequalities, toxicity, and odor. As better dyeing equipment becomes available, however, carrier dyeing seems to be gaining popularity.

Bleach: Bleaching of synthetic textiles is not normally a source of organic or suspended solids pollution. However, the process will generate dissolved solids, such as chlorides.

Final Scour: Acrylic and polyester receive a final scour and rinse. The raw waste products are synthetic detergent and pine oil for acrylic and antistatic lubricants and non-ionic syndet for polyesters. The pine oil and non-ionic syndet produce over 90 percent of the waste BOD in each case. Acrylic scour wastes average 700 ppm BOD; polyester wastes range from 500 to 800 ppm BOD.

Salt Bath: Rayon receives a salt bath and rinse after dyeing with direct dyes. The bath consists of 0 - 5 percent OWF detergent and 10 - 30 percent OWF salt. Wastes from this process are all due to hold-up from the salt bath and range from 400 to 12,000 ppm salt. Approximately 60 ppm BOD is produced.

Heat Setting: Dye take-up and shrinkage of synthetic fibers can be effected by heat-setting up to 450°F. Once this is done, the dimensional stability of the cloth cannot be changed without repeating the process at a higher temperature. Heat-setting is widely practiced and may occur at any of several places in the series of finishing processes. The most usual point of application is before dyeing. This may be a dry process using hot air, radiant heat, or a hot roll. Steam under pressure and hot water are also used. The two most prevalent methods in 1963 were hot air and steam. Wastes from this process are in the form of hot air, hot water, or steam.

Finishing: The last part of the overall finishing process may include such processes as:

Water proofing
Water-repellent treatment
Oil-repellent treatment
Resin finishing
Latex backing
Water retardant treatment
Modification of fabric hand
Drying

Any other minor specialized treatment falls into this category. These processes may contribute wastes, but the effect is generally not significant.

B. Significant Pollutants

Significant pollutants produced by synthetic fiber finishing are shown on Table I-1.

TABLE I-1 SIGNIFICANT POLLUTANTS

FIBER	PROCESS	LIQUID WASTE POLLUTANT	POSSIBLE AIR POLLUTION
Rayon	Chemical Preparation	Anti-static lubricants, Oil, Dye, Syndet (Synthetic Detergent)	
	Scour	Oil, Syndet, Anti-static lubricants	
	Scour and Bleach	Syndet H_2O_2	Vapors
	Salt Bath	Syndet, Chloride or Sulfate	
Acetate	Chemical Preparation	Oil, Dye, Syndet, Anti-static lubricants	
	Scour and Dye	Anti-static lubricants, Sulfonated Oils, Esters	
	Scour and Bleach	Syndet, H_2O_2, or Chlorine	Vapors
Nylon	Scour	Anti-static lubricants, Soap, Tetrasodium Pyrophosphate, Soda, Fatty Esters	
	Developed Dispersed Dye	Dye, $NaNO_2$, HCl (dilute), Developer, Sulfonated Oils	
	Bleach	Peracetic Acid	

TABLE I-1 SIGNIFICANT POLLUTANTS (cont'd)

FIBER	PROCESS	LIQUID WASTE POLLUTANT	POSSIBLE AIR POLLUTION
Acrylic	Cuprous ion, Phenol Dye	Dye, Formic Acid Wetting agent, Phenol, Aromatic Amines, Glyoxol, Sulfates	Fumes
	Thermosol Padding Dye	Acid	
	Bleach	Chlorite	
	Scour	Syndet, Pine Oil	
Polyester	Scour	Anti-static lubricants, Chlorite or Hypochlorite, Non-ionic Syndet	
	Thermosol Padding	Acid	
	Dye w/carrier	Monochlorobenzene, Hot Water, Dye	Toxic Fumes & Odor
		or Orthochlorobenzene, Dye, Hot Water	Odor & Fumes
		or Phenymethylcarbinol, Hot Water, Dye	Odor & Fumes
		or Salicylic Acid, Hot Water, Dye	Odor & Fumes
		or Benzoic Acid, Hot Water, Dye	Odor & Fumes
		or Orthophenylphenol, Dye	Odor & Fumes
	High Temp. & Press. Dye	Hot Water, Dye	Steam
	Bleach	Chlorite, $NaNO_2$, Acetic Acid, Oxalic Acid, Nitric Acid, Bisulfite, Proprietary Bleaches	Fumes

Table I-1 which projects subprocess trends in the synthetic finishing industry is the result of information received from operating plants, textile industry consultants, machinery manufacturers, chemical manufacturers, and a thorough survey of existing literature on the subject. It is intended to show the direction of the industry in 1967 on the basis of techniques now available. Since techniques are used in 1967 that were unheard of in 1950, it is entirely probable that scientific advances will make many of the subprocesses shown obsolete in the next ten years.

C. Process Water Reuse - 1964

It is estimated that this synthetic textile finishing industry reused approximately 10 percent of its process water in 1964, **and 90 percent was used only once.**

D. Subprocess Trends

As previously indicated in the description of fundamental manufacturing processes there are often alternate methods to accomplish a particular operation in the synthetic textile finishing process. Which method is used depends upon such factors as type and color of cloth being finished, type and size of process machinery available,skill of available operating personnel, length of run, and other factors. We have purposely left out the factor of wasteload produced because this does not seem to strongly influence subprocess selection. The plant manager is interested in increasing his production efficiency and product quality and any decrease in wasteload produced by the operation is merely a bonus. There are exceptions of course, but they are isolated

Trends in the rise of subprocesses are shown in Table I-2 for 1963 through 1982. No information is shown for 1950 due to the many major changes in the industry that have taken place.

TABLE I-2 SUBPROCESS TRENDS

Textiles and Processes	Estimated Percentage of Plants Employing Process				
	1950	1963	1967	1972	1982
Chemical Preparation					
rayon & acetate					
1. Scour		100	100	100	100
Scour: nylon, acrylic, polyester					
1. Soda Ash		10	5	5	2
2. Caustic Soda		10	15	20	20
3. Ammonium Hydroxide		60	65	70	70
4. Sodium Carboxymethyl Cellulose		50	60	70	70
Scour and Dye: rayon					
1. Direct		100	100	100	100
2. Naphthol		30	30	20	20
3. Developed		40	50	60	65
4. Vat		60	60	70	70
Scour and Bleach: rayon & acetate					
1. Hydrogen Peroxide		50	55	60	65
2. Hypochlorite		50	45	40	35
3. Sodium Chlorite		80	70	60	50
Dye Nylon:					
1. Dispersed		60	60	70	70
2. Acid		20	20	10	10
3. Direct		20	20	20	20
Dye Acrylic:					
1. Cationic w/cationic retarder		50	45	40	30
2. Cationic w/anionic retarder		10	10	5	5
3. Disperse		60	70	80	90
4. Basic		60	70	80	90
Dye Polyester:					
1. Conventional		5	5	5	-
2. w/Orthophenylphenol		3	20	20	20
3. w/Chlorinated benzenes		2	10	15	25
4. Benzoic or Salicylic Acid		40	20	10	-
5. Phenylmethyl carbinol		40	20	10	-
6. High Temp. & Pressure		5	15	25	35
7. Thermosol Padding		5	10	15	20

(Table I-2 Cont'd)

Textiles and Processes	Estimated Percentage of Plants Employing Process				
	1950	1963	1967	1972	1982
Bleach: nylon, acrylic, polyester					
1. Sodium Chlorite		30	20	10	10
2. Peracetic Acid		50	50	50	40
3. Hydrogen Peroxide & Sodium Hypochlorite		20	30	40	50
Final Scour: acrylic & polyester					
1. Soda Ash		10	5	2	2
2. Caustic Soda		10	10	20	30
3. Ammonium Hydroxide		70	70	80	85
4. Sodium Carboxymethyl Cellulose		30	40	50	60
Heat Set: all fibers					
1. Optional		80	85	90	95
Finishing: all fibers					
1. Optional		70	75	80	95

E. Waste Control Problems

Dyeing of polyester and acrylic presents a particularly difficult waste problem due to:

1. Odors of carriers
2. Toxic vapors of carriers
3. High BOD of carriers
4. Hot waste water

Use of pressure dyeing is increasing as machinery such as Burlington's Hy Press dye machine comes into use. Where carriers continue to be used, monochlorobenzene has the advantage of very low BOD in comparison to other carriers. It has the disadvantage of requiring venting facilities due to its toxic fumes.

F. Subprocess Technologies

This section of the report concerns itself with "typical" series of subprocesses representative of older (1950), prevalent (1963) and newer (1967) production process technology. It was hoped that such "typical" series could be described and further, that estimates of percentage of total plants and range of plant sizes could be associated with these production process technologies. It was possible to do this in a meaningful manner for the natural fibers, cotton and wool, but the synthetic textile finishing industry could not provide adequate data. The information appears to be simply not available on a national scale.

The reasons for this are many but most significant is the great variety of synthetic fibers being produced, the phenomenal growth of the industry, the recent development of the industry, the wide spread use of synethic-natural fiber blends, and the lack of a strong national manufacturers organization to collect and disseminate information.

As a typical example of the problems involved in deriving meaningful information about subprocess technologies, there are over 200 different dyes currently being used on nylon alone. Each of these dyes may require a different series of steps in preparing, dyeing and finishing the cloth. If the cloth is a blend with wool or cotton, this will introduce additional changes in the processes required for a particular dye operation. Since the dyeing operation is usually the major step, on a cost basis, in the production process, it is obvious that synthetic textile subprocess technology virtually defies precise analysis.

II. GROSS WASTE QUANTITIES

A. Daily Waste Quantities

The field of synthetic textiles is extremely complex because of the great number of different fibers being used, the fact that a significant proportion of synthetic fibers are blended with cotton and wool, and the industry is relatively new. The following Table II-1 provides ranges of quantities of pollutants produced for an average size plant arbitrarily given a production rate of 10,000 lb/day of cloth.

Since many of the fibers currently popular were not in use in 1950, we have not listed wasteload quantities for older technology. It was felt the industry has changed so drastically that such a listing would be meaningless.

Changes in subprocess chemistry and techniques in the synthetic textile industry are dictated largely by the few large manufacturers of synthetic fibers who maintain large research and development facilities. As a result this is a rapidly changing industry relative to the natural fiber (cotton and wool) industry.

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TABLE II-1 DAILY WASTE QUANTITIES

Subprocess	Fiber	Thousand Gal	Lb BOD	Lb SS	TDS
Scour	Nylon	60 - 80	300 - 380	200 - 400	300 - 500
	Acrylic	60 - 80	450 - 900	250 - 500	120 - 200
	Polyester	30 - 50	100 - 200	50 - 150	250 - 350
Scour & Dye	Rayon	20 - 40	480 - 730	0 - 30	250 - 390
	Acetate	40 - 60	410 - 590	-	-
Dye	Nylon	20 - 40	70 - 130	10 - 200	200 - 340
	Acrylic	20 - 40	20 - 400	20 - 420	60 - 90
	Polyester	20 - 40	230 - 1380	50 - 200	300 - 2000
Salt Bath	Rayon	5 - 15	0 - 30	-	200 - 2000
Final Scour	Acrylic	80 - 100	120 - 250	20 - 60	40 - 120
	Polyester	20 - 40	150 - 250	30 - 70	100 - 500
Special Finishing (optional)	Rayon	5 - 15	20 - 800	30 - 1000	30 - 1000
	Acetate	30 - 50	20 - 800	30 - 1000	30 - 1000
	Nylon	40 - 60	20 - 800	30 - 1000	30 - 1000
	Acrylic	50 - 70	20 - 800	30 - 1000	30 - 1000
	Polyester	10 - 30	20 - 800	30 - 1000	30 - 1000
Total	Rayon	30 - 70	140 - 2400	200 - 3000	200 - 3000
	Acetate	70 - 110	140 - 2400	200 - 3000	200 - 3000
	Nylon	120 - 180	140 - 2400	200 - 3000	200 - 3000
	Acrylic	210 - 290	170 - 2900	250 - 4000	250 - 4000
	Polyester	80 - 160	420 - 7800	300 - 6000	300 - 6000

B. Wasteload Production Rates

The following Table II-2 estimates average quantities of wastes produced per 1000 lb of cloth finished. Due to the great number of variations, ranges of values are given which are intended to include most common variations.

TABLE II-2 AVERAGE WASTELOAD PRODUCTION RATES PER 1000 LB OF CLOTH PRODUCED

Subprocess	Fiber	Volume Gal.	BOD Lb	SS Lb	TDS Lb
Scour	Nylon	6,000 - 8,000	30 - 40	20 - 40	30 - 50
	Acrylic	6,000 - 8,000	45 - 90	25 - 50	12 - 20
	Polyester	3,000 - 5,000	15 - 25	5 - 15	25 - 35
Scour & Dye	Rayon	2,000 - 4,000	50 - 70	0 - 3	25 - 39
	Acetate	4,000 - 6,000	40 - 60	-	-
Dye	Nylon	2,000 - 4,000	5 - 20	1 - 20	20 - 34
	Acrylic	2,000 - 4,000	2 - 40	2 - 42	6 - 9
	Polyester	2,000 - 4,000	15 - 800	5 - 20	30 - 200
Salt Bath	Rayon	500 - 1,500	0 - 3	-	20 - 200
Final Scour	Acrylic	8,000 - 10,000	10 - 25	2 - 6	4 - 12
	Polyester	2,000 - 4,000	15 - 25	3 - 7	10 - 50
Special Finishing	Rayon	500 - 1,500	20	3 - 50	3 - 100
	Acetate	3,000 - 5,000	40	3 - 50	3 - 100
	Nylon	4,000 - 6,000	10	3 - 50	3 - 100
	Acrylic	5,000 - 7,000	60	3 - 50	3 - 100
	Polyester	1,000 - 3,000	2 - 80	3 - 50	3 - 100
Total	Rayon	3,000 - 7,000	20 - 40	20 - 90	20 - 500
	Acetate	7,000 - 11,000	40 - 50	20 - 60	20 - 300
	Nylon	12,000 - 18,000	35 - 55	20 - 40	20 - 300
	Acrylic	21,000 - 29,000	100 - 150	25 - 150	25 - 400
	Polyester	8,000 - 16,000	120 - 250	30 - 160	30 - 600

C. Total Wasteload

Research in U.S. Department of Commerce statistics reveals the following data for 1963:

Finished Synthetic Fabric
- Cellulosics: 505 million lb
- Non-cellulosics: 470 million lb

Based upon this data and the wasteload quantities from Table II-2, we estimate the following gross wasteload quantities produced in 1963.

Textile	Volume (Billion Gal)	BOD (Million lb)	SS (Million lb)	TDS (Million lb)
Rayon	4.8	59	65	34
Acetate	2.2	12	13	26
Nylon	6.1	20	20	42
Acrylic	1.8	9	5	40
Polyester	2.3	77	75	150
	17.2	177	178	292

D. Gross Wasteload Projections

The following projections are based upon the projected value added in manufacture figures provided by FWPCA, estimate of increase in percentage of waste treatment techniques, and reduction of waste generated per unit of production.

	1968	1967	1970	1971	1972	1977	1982
Wastewater (Billion Gal)	25	27	28	29	30	36	39
BOD (Million lb)	264	278	288	301	314	375	409
SS (Million lb)	266	280	291	304	316	379	412
TDS (Million lb)	524	563	584	608	633	760	827

E. Seasonal Variations

There are no significant seasonal variations.

III. WASTE REDUCTION PRACTICES

A. Processing Practices

Table III-1, outlines the relative pollution reduction potentials of the various alternative subprocesses used in the synthetic textile industry. The "older" technological method in each case is used as the basis for comparison. The values shown are generally the highest reported reductions for a particular alternate subprocess.

TABLE III-1 PROCESS POLLUTION REDUCTION

Textiles & Processes	Percent Reduction		
	Older	Prevalent	Newer
Chemical Preparation: Rayon and Acetate Lower BOD Chem.	0	2	5
Scour: Nylon, Acrylic and Polyester Continuous Scour Machine	0	10	15
Scour and Dye: Rayon and Acetate Continuous Machines	0	10	15
Scour and Bleach: Rayon and Acetate Continuous Machines	0	10	15
Dye: Nylon	0	Depends on Dye	Depends on Dye
Dye: Acrylic	0		
Dye: Polyester High temp. pressure dye machine	0	80	80
Bleach: Nylon, Acrylic, Polyester	0		
Continuous Bleaching Machine	0	5	10
Final Scour: Acrylic and Polyester Continuous Scour Machine	0	10	20
Special Finishing: All Fibers, Optional	0	Depends on Finish	

Sequences in which subprocessing techniques affecting wasteload production must be applied due to technological considerations are as follows:

1. First scour must precede or be concurrent with dye or bleach to remove sizes remaining from the weaving operation.

2. Final scour or salt bath must follow dye to remove excess dye and other materials.

3. Special finishing if applied must follow all other processing.

Interdependencies among processing techniques which affect wasteload removal efficiencies or cost are as follows:

1. Any heavy metal ions in the waste will normally inhibit biological treatment such as trickling filters or activated sludge. If toxic ion is present, it may have to be removed chemically prior to further treatment or discharge.

2. Toxic carriers, such as chlorinated benzenes, may inhibit bacterial growth in biological treatment. These carriers might be removed and reused because of their high cost as well as their toxic effect.

3. Introduction of subprocesses which produce little or no waste will affect wasteload removal cost. The thermosol dyeing process is an example in that it produces little liquid waste. Some special finishing processes use padding to apply the finish and therefore produce little waste.

B. Treatment Practices

1. Removal Efficiencies

Efficiencies of treatment processes with synthetic textile wastes are essentially the same as with other wastes of similar strength. Typical wasteload removal efficiencies are shown in Table III-2.

TABLE III-2 TREATMENT REMOVAL EFFICIENCIES

Treatment Method	Removal Efficiency (Percent)		
	BOD	SS	TDS
Screening	0 - 5	5 - 20	0
Plain Sedimentation	5 - 15	15 - 60	0
Chemical Precipitation	25 - 60	30 - 90	0 - 50
Trickling Filter	40 - 85	80 - 90	0 - 30
Activated Sludge	70 - 95	85 - 95	0 - 40
Lagoon	30 - 80	30 - 80	0 - 40
Aerated Lagoon	50 - 95	50 - 95	0 - 40

2. Rates of Adoption

The tremendous growth rate of the synthetic textile industry is expected to continue and increase as various new materials (modifications of existing fibers) and new fibers are introduced to the public. Concurrent with this growth, a nearly equal increase in wasteload seems imminent. This, along with pressures by regulatory agencies regarding stream pollution, will lead to an increased rate of adoption of waste treatment practices in the future.

Synthetic textile wastes have generally been treated by biological methods with good removal efficiency at reasonable cost. In the future, it is expected that water requirements per unit production will be reduced resulting in a plant effluent which will be higher in pollution concentration and lower in volume. Therefore, the adoption of more elaborate waste treatment facilities utilizing pretreatment and tertiary polishing can be expected.

Toxic metallic ions in dye wastes can retard biological oxidation when present in high concentrations. Chemical pretreatment may therefore become a requirement, or the industry may choose to adopt treatment by chemical coagulation as the principal method.

The following estimates are based on the above assumptions and industry growth projections provided by the FWPCA.

Year	Municipally Treated Waste Percent	Avg BOD Reduction Percent	Industry Treated Waste Percent	Avg BOD Reduction Percent	Total Reduction Percent
1967	50	85	25	65	58
1968	51	85	26	66	60
1969	52	85	27	67	62
1970	53	86	28	68	64
1971	54	86	29	69	66
1972	55	86	30	70	68
1977	68	87	32	73	82
1982	71	88	34	76	88

Sequences of treatment due to technical considerations are:

(a) pH adjustment may precede other chemical treatment to reduce use of costly chemicals.

(b) Normally, suspended solids removal precedes biological treatment methods such as activated sludge or trickling filter. Lagooning, oxidation ponds, and certain activated sludge modifications may not require SS removal.

(c) Sludge treatment and ultimate disposal follow sludge producing processes, such as settling.

Substitute techniques may be:

(a) Biological and chemical treatments are, under certain circumstances, substitutes for each other. In other situations they may be part of the same waste treatment process.

(b) Sometimes fine screening may be substituted for sedimentation basins.

(c) Normally the activated sludge and the trickling filter process are not used together in the same system.

3. Discharge to Municipal Sewers

PERCENTAGE OF INDUSTRY'S WASTE
DISCHARGED TO MUNICIPAL SEWER

Year	1950	1963	1967	1972
Percent	35	45	50	55

It should be noted that much of the synthetic textile production is used in blends with cotton and wool. In addition most finishing plants are equipped to finish either natural or man-made fibers. For these reasons it is extremely difficult to seperate out wastes from synthetic textiles and arrive at an estimate of the percentage being discharged to municipal sewers. The above is our best estimate based on overall industry data and trends.

Problems associated with treating textile wastes in municipal facilities are dependent primarily on the volume ratio of the domestic sewage to the industrial waste. If the textile waste is only a small percentage of the total volume entering the municipal plant no problems are encountered. If, however, the textile waste constitutes a significant percentage of the total volume it may be necessary to make special provisions. These would normally include holding and equalization at the textile finishing plant, pH control, chemical precipitation of any toxic constituents and possibly chemical treatment for color removal.

C. By-Product Utilization

There would be an adequate market for wastes reclaimed in synthetic fiber finishing if economically feasible methods were developed. This is due to the fact that all liquid wastes contain chemicals used in the finishing (or sizing) itself and could be reused if reclaimed. (The one exception to this is the one percent OWF Nylon extracted in the scour). All carriers presently recovered are reused. It is not economical to reclaim the other chemicals, such as spent developed dye bath. Thermal wastes can be reused by heat transfer methods.

D. Net Waste Quantities - 1963

BOD - 96 million lb
SS - 71 million lb
TDS - 322 million lb

E. Projected Net Wasteload

It is expected that the gross pollution load produced by the synthetic textile finishing industry will increase significantly because of rapidly increasing production.

It is anticipated, however, that the organic and suspended solids pollution reaching the nations' watercourses will remain essentially constant because of greater percentage of waste treated and higher waste treatment efficiencies. This is not true of the dissolved inorganic matter since most prevailing waste treatment methods do not significantly reduce dissolved minerals. Tertiary treatment techniques capable of removing dissolved inorganic matter are currently under extensive study, but it is unlikely that they will come into significant use prior to 1982.

TABLE III-3 PROJECTED NET WASTELOADS

Year	Waste	Gross Produced (million lb)	Removed (percent)	Net Reaching Watercourses (million lb)
1963	BOD	177	54	96
	SS	178	60	71
	TDS	358	10	322
1967	BOD	252	58	106
	SS	254	69	89
	TDS	510	10	459
1968	BOD	264	60	106
	SS	266	67	88
	TDS	524	10	472
1969	BOD	278	62	105
	SS	280	69	87
	TDS	563	10	507
1970	BOD	288	64	103
	SS	291	71	85
	TDS	584	11	520
1971	BOD	301	66	102
	SS	304	73	82
	TDS	608	11	541
1972	BOD	314	68	100
	SS	316	75	79
	TDS	633	12	557
1977	BOD	375	75	94
	SS	379	83	64
	TDS	760	15	645

IV. COST INFORMATION

A. Existing Facilities Costs

We estimate that the total replacement value of synthetic textile finishing industry-owned and-operated waste reduction facilities was $6 million in 1966 and that the total annual operating and maintenance cost was 0.5 million dollars.

The above values are for industry owned and operated plants only. We estimate that in 1966 approximately 50 percent of the waste was discharged into and treated by municipal systems. Since industry pays taxes and surcharges to support these facilities, the true industry cost exceeds the foregoing amounts.

We estimate that the replacement value of that portion of municipal facilities construction attributable to this industry's waste is $10 million. On the same basis, the annual operating and maintenance cost is estimated at $1.0 million.

Totals: Replacement Value - $16 million in 1966.
Operating & Maintenance - $1.5 million in 1966.

B. Processing and Treatment Costs

This portion of the survey analyzes costs involved in subprocesses and end of line treatment. These are further broken down into size of plant and state of technology; i.e., older, prevalent and newer. Because of the wide ranges in the information feedback from the textile industry, we have inserted ranges in the following tables. In addition, we have added a table which gives cost data on the entire synthetic textile finishing industry and relates costs of waste treatment to cost of production. We believe this latter table gives a much more accurate picture of the present industry cost situation than do the tables preceding it.

We have found that new machinery for subprocesses is purchased by the industry on the basis of increasing production efficiency and product quality - not on the basis of decreasing the pollution load produced by the subprocess. Any such decrease is merely a bonus in most cases.

It should also be noted that the end of the line waste treatment has virtually no relationship to the technology of the process that created the waste or the size of the finishing plant; i.e., an older technology plant may have an extremely efficient, modern, waste treatment facility, and a modern, efficient finishing plant may have no waste treatment facility at all. With few exceptions, the end of the line treatment selected is primarily on the basis of requirements imposed by regulating agencies reponsible for the water courses being affected.

It should be noted also that we are required to estimate costs for plants incorporating pure states of technology, i.e., completely old, completely prevalent, completely advanced. Few such plants exist. Most plants are mixtures of varied subprocess technologies, since they have been modernized in stages over a relatively long period of time.

Several definitions are necessary for the following tables:

Old Technology - That technology new in 1950.
Prevalent Technology - That technology new in 1963.
Advanced Technology - That technology new in 1967.
Small Plant - Produces 10,000 lb cloth/day.
Medium Plant - Produces 20,000 lb cloth/day.
Large Plant - Produces 60,000 lb cloth/day.
Capital Cost - Equivalent 1966 cost.
Annual Operating and Maintenance Expenditure - Equivalent 1966 cost.
Economic Life - The economic life is the length of time the machine or structure can be expected to compete with advancing technology. It is an estimate of the length of time required for economic obsolescence. This will vary greatly in different industries depending upon the nature of the product, dynamics of industry growth, etc.

TABLE IV-1

INDUSTRY SYNTHETIC TEXTILE - SMALL PLANT - OLDER TECHNOLOGY

1950 Technology 10,000 Lb/Day Plant	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
Alternative Subprocesses	($1000)	($1000)	(Years)*
Chemical Preparation	4-9	3- 6	10
Scouring	11-23	8- 15	10
Dyeing	80-160	55-105	10
Bleaching	11-23	8- 15	10
Final Scouring	11-23	8- 15	10
Salt Bath	7-14	5- 9	10
Heat Set	7-14	5- 9	10
Special Finishing	4-9	3- 6	10
Rest of Plant	90-185	60-135	15
TOTAL	225-460	155-315	

End of Line Treatment			
Screening	0.3-2.6	0.1-0.3	
Sedimentation	1.0-3.2	0.1-0.5	
Chemical Precipitation	1.3-4.9	0.7-2.6	
Trickling Filter	2.2-9.8	0.4-1.6	
Activated Sludge	2.8-15	0.5-2.6	
Lagooning	0.2-1.3	0.1-0.2	
Aerated Lagoon	0.7-3.7	0.2-0.6	

* Approximate

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-2

INDUSTRY SYNTHETIC TEXTILE - MEDIUM PLANT - OLDER TECHNOLOGY

1950 Technology 20,000 Lb/Day Plant	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
Alternative Subprocesses	($1000)	($1000)	(Years)*
Chemical Preparation	10-15	5- 10	8
Scouring	20-40	15- 30	8
Dyeing	140-290	100-210	8
Bleaching	20-40	15- 30	8
Final Scouring	20-40	15- 30	8
Salt Bath	10-25	10- 20	8
Heat Set	10-25	10- 20	8
Special Finishing	10-15	5- 10	8
Rest of Plant	160-350	115-240	15
TOTAL	400-840	290-600	
End of Line Treatment			
Screening	0.5-5.0	0.1-0.9	
Sedimentation	1.2-9.1	0.2-1.0	
Chemical Precipitation	2.5-9.7	1.3-9.0	
Trickling Filter	4.3-20	0.7-3.0	
Activated Sludge	5.5-30	0.9-5.0	
Lagoon	0.4-2.6	0.1-0.3	
Aerated Lagoon	1.2-7.4	0.4-2.2	

* Approximate

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-3

INDUSTRY SYNTHETIC TEXTILE - LARGE PLANT - OLDER TECHNOLOGY

1950 Technology 60,000 lb/Day Plant	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
Alternative Subprocesses	($1000)	($1000)	(Years)*
Chemical Preparation	20 - 40	10- 30	6
Scouring	50 -100	30- 70	6
Dyeing	350 -700	210- 500	6
Bleaching	50 -100	30- 90	6
Final Scouring	50 -100	30- 70	6
Salt Bath	30 - 60	20- 40	6
Heat Set	30 - 60	20- 40	6
Special Finishing	20 - 40	10- 30	6
Rest of Plant	400 -800	240- 570	15
TOTAL	1000 -2000	600-1420	

End of Line Treatment			
Screening	1.5 - 15	0.4 - 1.5	
Sedimentation	3.4 - 19	0.6 - 3.0	
Chemical Precipitation	7.3 - 30	3.7 -15	
Trickling Filter	13 - 58	1.9 - 9.0	
Activated Sludge	16 - 87	2.6 -15	
Lagoon	1.2 - 7	0.2 - 0.8	
Aerated Lagoon	3.7 - 22	1.2 - 6.7	

* Approximate

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does <u>not</u> include any sewer <u>collection system</u> costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-4

INDUSTRY SYNTHETIC TEXTILE - SMALL PLANT - PREVALENT TECHNOLOGY

1963 Technology 10,000 Lb/Day Plant	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
Alternative Subprocesses	($1000)	($1000)	(Years)*
Chemical Preparation	5-10	3- 6	10
Scouring	10-30	8- 15	10
Dyeing	100-210	45-105	10
Bleaching	15-30	8- 15	10
Final Scouring	15-30	8- 15	10
Salt Bath	10-20	5- 9	10
Heat Set	10-20	5- 9	10
Special Finishing	5-10	3- 6	10
Rest of Plant	120-240	53-120	15
TOTAL	290-600	138-300	

End of Line Treatment			
Screening	0.2 2.4	0.1-0.2	
Sedimentation	0.5- 3.0	0.1-0.5	
Chemical Precipitation	1.2-4.8	0.6-2.4	
Trickling Filter	2.1-9.6	0.3-1.4	
Activated Sludge	2.7-14	0.4-2.4	
Lagoon	0.2-1.2	0.1-0.2	
Aerated Lagoon	0.6-3.6	0.2-0.5	

* Approximate

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-5

INDUSTRY SYNTHETIC TEXTILE - MEDIUM PLANT - PREVALENT TECHNOLOGY

1963 Technology 20,000 Lb/Day Plant	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
Alternative Subprocesses	($1000)	($1000)	(Years)*
Chemical Preparation	10- 20	5- 10	8
Scouring	25- 50	15- 30	8
Dyeing	180- 370	90-190	8
Bleaching	25- 50	15- 30	8
Final Scouring	25- 50	15- 30	8
Salt Bath	15- 30	10- 20	8
Heat Set	15- 30	10- 20	8
Special Finishing	10- 20	5- 10	8
Rest of Plant	215- 420	100-220	15
TOTAL	520-1040	265-560	

End of Line Treatment		
Screening	0.5- 4.8	0.1-0.5
Sedimentation	1.1- 9.0	0.1-1.0
Chemical Precipitation	2.4- 9.6	1.2-4.8
Trickling Filter	4.2-19	0.6-2.9
Activated Sludge	5.4-29	0.8-4.8
Lagooning	0.4 2.4	0.1-0.3
Aerated Lagoon	1.2- 7.2	0.4-2.2

* Approximate

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used).
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

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TABLE IV-6

INDUSTRY SYNTHETIC TEXTILE - LARGE PLANT - PREVALENT TECHNOLOGY

1963 Technology 60,000 lb/Day Plant	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
Alternative Subprocesses	($1000)	($1000)	(Years)*
Chemical Preparation	25 - 50	10- 25	6
Scouring	65 - 130	30- 70	6
Dyeing	455 - 910	200-470	6
Bleaching	65 - 130	30- 70	6
Final Scouring	65 - 130	30- 70	6
Salt Bath	40 - 80	15- 40	6
Heat Set	40 - 80	15- 40	6
Special Finishing	25 - 50	10- 25	6
Rest of Plant	520 -1040	230-540	15
TOTAL	1300 -2600	570-1350	

End of Line Treatment			
Screening	1.4 - 14	0.4 - 1.4	
Sedimentation	3.3 - 18	0.5 - 2.9	
Chemical Precipitation	7.2 - 29	3.6 -14	
Trickling Filter	13 - 58	1.8 - 9	
Activated Sludge	16 - 86	2.5 -14	
Lagoon	1.1 - 7.2	0.2 - 0.7	
Aerated Lagoon	3.6 - 22	1.1 - 6.5	

* Approximate

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-7

INDUSTRY SYNTHETIC TEXTILE - SMALL PLANT - NEWER TECHNOLOGY

1967 Technology 10,000 Lb/Day Plant	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
Alternative Subprocesses	($1000)	($1000)	(Years)*
Chemical Preparation	5- 10	3- 6	10
Scouring	15- 35	6- 14	10
Dyeing	110-220	45-100	10
Bleaching	15- 35	6- 14	10
Final Scouring	15- 35	6- 14	10
Salt Bath	10- 20	3- 8	10
Heat Set	10- 20	3- 8	10
Special Finishing	5- 10	3- 6	10
Rest of Plant	125-255	55-120	15
TOTAL	310-640	130-290	
End of Line Treatment			
Screening	0.2- 2.4	0.1-0.3	
Sedimentation	0.5- 3.0	0.1-0.5	
Chemical Precipitation	1.2- 4.8	0.6-2.4	
Trickling Filter	2.1- 9.6	0.3-1.4	
Activated Sludge	2.7-14	0.4-2.4	
Lagoon	0.2- 1.2	0.1-0.2	
Aerated Lagoon	0.6- 3.6	0.2-0.6	

* Approximate

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-8

INDUSTRY SYNTHETIC TEXTILE - MEDIUM PLANT - NEWER TECHNOLOGY

1967 Technology 20,000 Lb/Day Plant	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
Alternative Subprocesses	($1000)		(Years)*
Chemical Preparation	10- 20	5- 10	8
Scouring	30- 60	15- 30	8
Dyeing	195-400	90-190	8
Bleaching	30- 60	15 - 30	8
Final Scouring	30- 60	15 - 30	8
Salt Bath	15- 35	5 - 15	8
Heat Set	15- 35	5- 15	8
Special Finishing	10- 20	5- 10	8
Rest of Plant	225-460	105-210	15
TOTAL	560-1150	260-540	
End of Line Treatment			
Screening	0.5- 4.8	0.1-0.5	
Sedimentation	1.1- 9.0	0.2-1.0	
Chemical Precipitation	2.4- 9.6	1.2-4.8	
Trickling Filter	4.2-19	0.6-2.9	
Activated Sludge	5.4-29	0.8-4.8	
Lagoon	0.4- 2.4	0.1-0.3	
Aerated Lagoon	1.2- 7.2	0.4-2.2	

* Approximate

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

TABLE IV-9

INDUSTRY SYNTHETIC TEXTILE - LARGE PLANT - NEWER TECHNOLOGY

1967 Technology 60,000 lb/Day Plant	Capital Costs	Annual Operating & Maintenance Expenditures	Economic Life
Alternative Subprocesses	($1000)	($1000)	(Years)*
Chemical Preparation	30 - 55	10 - 25	6
Scouring	70 - 140	25 - 65	6
Dyeing	490 - 980	200 - 475	6
Bleaching	70 - 140	25 - 65	6
Final Scouring	70 - 140	25 - 65	6
Salt Bath	40 - 85	15 - 40	6
Heat Set	40 - 85	15 - 40	6
Special Finishing	30 - 55	10 - 25	6
Rest of Plant	560 -1120	235 - 530	15
TOTAL	1400 -2800	560 - 1330	
End of Line Treatment			
Screening	1.4 - 14	0.4 - 1.4	
Sedimentation	3.3 - 18	0.5 - 2.9	
Chemical Precipitation	7.2 - 29	3.6 -14	
Trickling Filter	13 - 58	1.8 - 8.7	
Activated Sludge	16 - 86	2.5 -14	
Lagoon	1.1 - 7	0.2 - 0.7	
Aerated Lagoon	3.6 - 22	1.1 - 6.5	

* Approximate

Special Notes:

1. All costs are equivalent 1966 costs. (To determine actual costs for an earlier year, an appropriate engineer construction cost factor may be used.)
2. Percentage of pollution reduction achieved by a particular end of the line treatment process is simplified and assumed to be the same in compared years. For example, it is assumed that the screening process in 1950 would achieve the same efficiency of pollution reduction as screening in 1963 and 1967.
3. The end of the line treatment does not include any sewer collection system costs. It is assumed that the waste treatment facility is located adjacent to the industrial waste source.

These assumptions were considered necessary to comply with the contract while permitting comparison of waste treatment costs achieved, first, by lesser waste volume and strength generated by a plant per unit of product and secondly, by increased efficiency in certain end of the line waste treatment processes.

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TABLE IV-10

SUMMARY OF PRODUCTION AND WASTE TREATMENT COSTS

Synthetic Textile Finishing

Item	Quantity
Total Production	975 Million lb
Total value added in manufacture[1]	179 Million $
Average unit value added in manufacture	.18 $/ lb
Estimated replacement value of waste reduction facilities[2]	16 Million $
Annual amortized cost of facilities at 7% and 10 yr life[2]	2.3 Million $
Estimated annual waste reduction operating and maintenance cost[2]	1.5 Million $
Average industry cost of waste treatment per unit of production	.004 $/ lb
Total waste reduction costs as percent of total production cost	2.2 Percent

The above table is a comparison of the total capital, operating, and maintenance cost per year of end of the line waste treatment to the total cost of production per year. These are industry-wide estimates and individual plants may deviate considerably.

1. From the Business and Defense Services Administration, U. S. Department of Commerce, 1967.

2. Estimated replacement value, estimated amortization, and estimated annual operating costs include an estimate of the cost of municipal facilities attributable to this industry's wastes.

NYLON (POLYAM
INTERMEDIAT
4-6% MOISTU

ACRYLICS
HYDROPHOBIC
SPUN-DYED

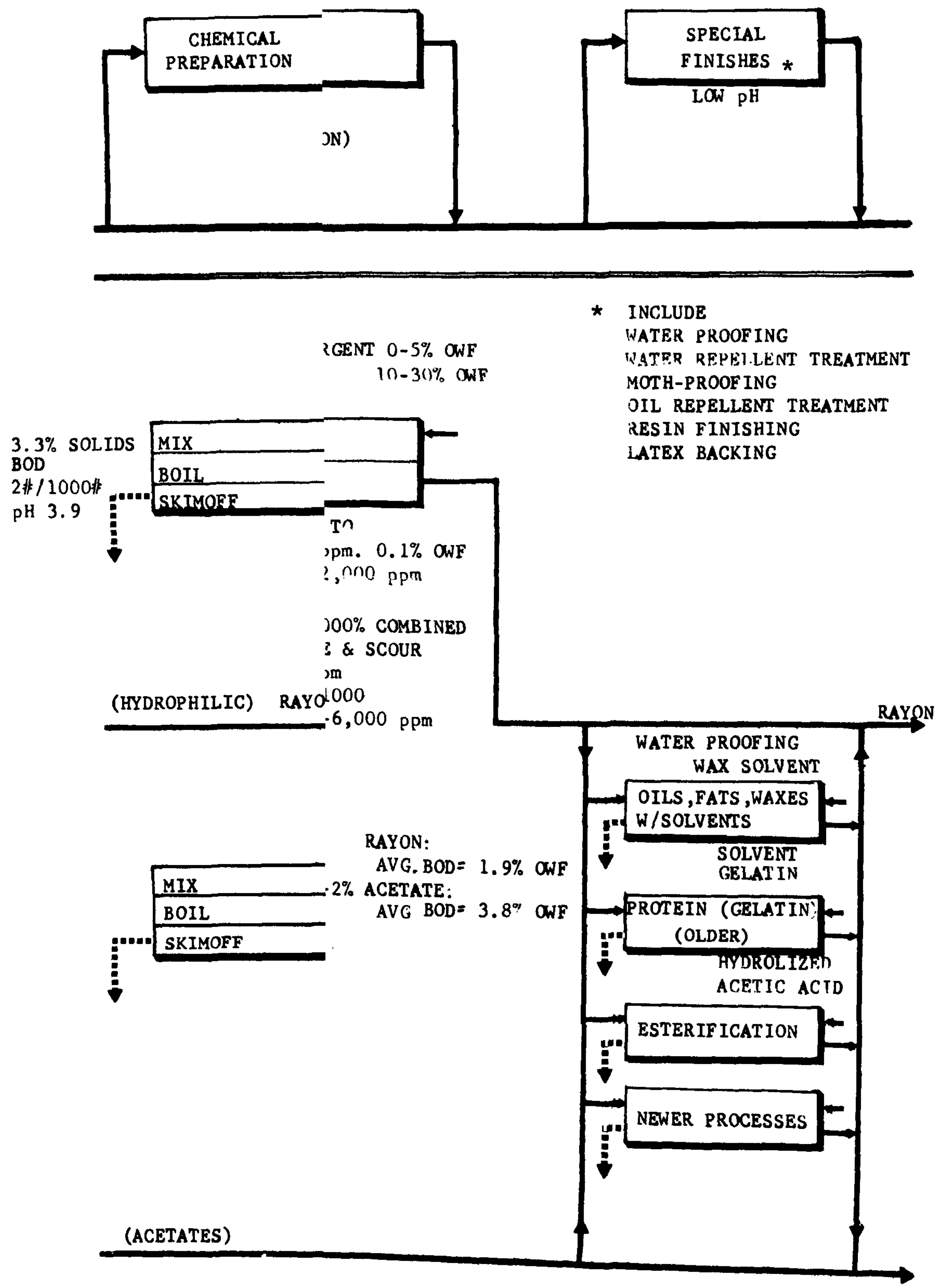
MODACRYLIC

POLYESTERS

1.6% MOIS?

287-027 O - 68 (Face p. 120) No. 5

Prepared for F.W



I.W.P. NO. 4, CELLULOSE SYNTHETIC TEXTILE FINISHING PROCESS FLOW CHART - SIC 2262

PLATE 2

Prepared for F.W

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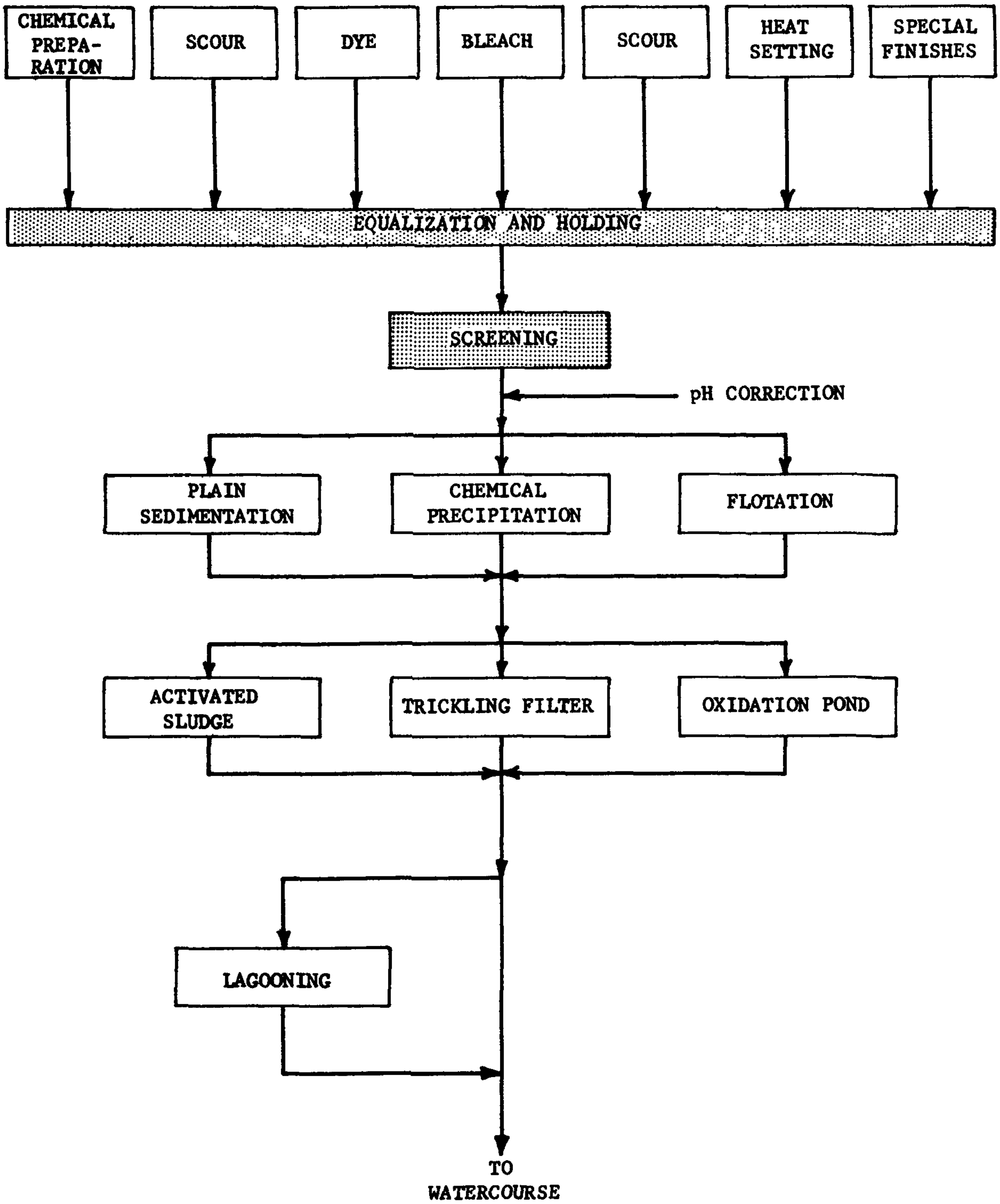

I.W.P. NO. 4

SYNTHETIC TEXTILE FINISHING

WASTE TREATMENT FLOW CHART-SIC 2262

PLATE 3

Prepared for F.W.P.C.A.

SYNTHETIC TEXTILE FINISHING

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APPENDIX I

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APPENDIX II

GLOSSARY

Aeration - The act of supplying with oxygen.

Aerobic - Living or active in the presence of oxygen.

Acetate - A manufactured fiber in which the fiber-forming substance is cellulose acetate.

Acid Cracking - A process in which complex chemical structures are broken up by the action of acid.

Acrylic - A manufactured fiber in which the fiber-forming substance is any long chain synthetic polymer composed of at least 85 percent by weight of acrylonitrile units.

Activated Sludge - A process for treating liquid waste by aeration and recirculation of biologically active sludge.

Anaerobic - Living or active in the absence of oxygen.

Beck Dyeing - A continuous process for dyeing cloth by moving it through a large vat containing the dye bath and rollers.

Bleaching - The procedure, other than by scouring only, of improving the whiteness of a textile material by oxidation or reduction of the coloring matter.

BOD - Biochemical Oxygen Demand - The weight of oxygen required to biological oxidize an organic waste over a specified period of time.

Carbonizing - To convert to residue of carbon, as by fire or chemical action, to char.

Carding - The separation and partial cleaning by processing of a tangled or matted mass of fibers to a flimsy web by working the fibers between two closely spaced, relatively moving surfaced, clothed with sharp points.

Cationic - Containing positively charged particles or ions, usually applied to an electrolyzed solution.

Causticizing - Treating with a corrosive chemical capable of eating or destroying.

Coagulation - The change from a liquid to a thickened, curd-like state.

COD - Chemical Oxygen Demand - A measure of the organic pollution.

Copperas - Crystalized ferrous sulfate.

Counter-Current - Flow of wash water in opposition to flow of product such that the product encounters increasingly cleaner water.

Dacron - A registered trademark of E. I. duPont de Nemours and Company identifying a particular synthetic fiber.

Desizing - Removal of sizing, anti-static compounds and lubricants.

Drawing - Stretching freshly spun synthetic fibers to several times their original length.

Effluent - Polluted water discharged from a process.

Equalization - The process of combining two or more dissimilar wastes to produce a uniform composite.

Filament - A variety of fiber having an extreme length, not readily measured.

Filler - Nonfibrous material, such as insoluble clays or gypsum, together with starches, gums, etc., added to a fabric to increase its weight or to modify the appearance or handle of the fabric; also referred to as back-sizing.

Full - To thicken by moistening, heating and pressing, as cloth; to scour, cleanse, and thicken cloth in a mill.

Gray Goods - Woven or knitted fabrics which have received no bleaching, dyeing or finishing treatment.

Hydrophobic - Resistant to the absorption of water, "water hating".

Hydrophilic - Easily absorbs water, "water friendly".

Lagooning - A liquid waste treatment process of holding the waste in shallow ponds for a period of several hours to allow absorption of oxygen.

Moisture Regain - The moisture in a material determined under prescribed conditions and expressed as a percentage of the weight of the oven-dried specimen.

Neutralize - To adjust the pH of a solution to seven (neutral) by the addition of an acid or a base.

Nylon - A manufactured fiber in which the fiber-forming substance is any long chain synthetic polyamide having recurrent amide groups as an integral part of the polymer chain.

Olefin - A newly developed synthetic fiber.

Orlon - A registered trademark of E. D. duPont de Nemours and Company identifying a particular synthetic fiber.

Polyamide - See "Nylon".

Polyester - A manufactured fiber in which the fiber forming substance is any long chain synthetic polymer composed of at least 85 percent by weight of an ester of a dihydric alcohol and terepthalic acid.

Process - A series of actions or operations defintely conducting to an end; continuous operation or treatment, especially as in manufacture.

Raw Wool - Wool as taken from sheep, containing approximately 50% grease and dirt.

Rayon - A manufactured fiber composed of regenerated cellulose, as well as manufactured fibers composed of regenerated cellulose in which substitutes have replaced not more than 15 percent of the hydrogens of the hydroxyl groups.

Scour - To rub hard for the purpose of cleansing; to make clean and bright by friction.

Screening - Separation of solid material from liquid waste by passing the waste through screens.

Sedimentation - The act or process of settling matter to the bottom of a liquid.

Singe - To remove the nap of cloth by exposing it to scorching heat.

Sizing - A generic term for compounds which, when applied to yarn or fabric, form a more or less continuous solid film around the yarn and individual fibers.

Skin - A continuous strand of yarn in the form of a flexible coil having a large circumference in proportion to its thickness.

Slashing - To cut by sweeping strokes, to cut in long slits.

Sludge - The precipitated solid matter produced by water and sewage treatment processes.

Steep - To soak in a liquid.

Subprocess - An alternate method of conducting a process.

Suint - Excretions from the sweat glands of sheep, principally potash salts.

Trickling Filtration - A liquid waste treatment process involving trickling the waste through a bed of stone or other inert material.

Yarn - A generic term for a continuous strand of textile fibers, filaments or material in a form suitable for knitting, weaving, or otherwise intertwining to form a textile fabric.

Yield - The number of finished square yards per pound of fabric.

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