A WATER RESOURCES GUIDE FOR TEXTILES

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Presented to
The Faculty of the Graduate Division
by
Telford Edwin Elders

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Textiles

Georgia Institute of Technology
September, 1966
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A WATER RESOURCES GUIDE FOR TEXTILES

Approved:

Chairman

Date approved by Chairman: Sept 21, 1960
Dedicated to

Dr. William L. Hyden

For His Guidance
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SUMMARY

Georgia's largest industry is textile manufacturing which produces a wide variety of products.

In the process of preparing an appealing and functional item, textile goods are finished. Finishing requires several gallons of water per pound of goods finished. In Georgia, millions of gallons of water are used daily to finish the large volume of textile products manufactured.

When water is used by the textile industry, it is not consumed but requires some form of disposal. Georgia has had modest industrial activity and a low population density in past years. This condition permitted disposal of waste water without treatment. Also, ample raw water of good quality was available for textile processing.

Today, water is still abundant, but as the population density and industrial activity has increased, the quality of the raw surface water in Georgia's streams and lakes has been lowered. The change in the quality of the surface water requires surface water users to improve their water purification if they are to produce high quality water for a supply system, either industrial or domestic.

Federal and state laws have been passed which are designed to control the quality of the raw water in lakes and streams. These laws will require the treatment of waste-water discharge. The Georgia textile industry has indicated it will face and attempt to solve its water problems.
The objective of this thesis is to present suggestions, data, and general directions to assist the industry in solving its water problems. Five basic areas were covered. They are: legal stipulations, water supply, water purifications, waste-water treatment, and in-plant modifications. A discussion of each area is presented. Those laws, Federal and State, that govern water and waste-water are presented in an outline form. The engineering and technical problems of treatment methods and the advantages of each method are presented to assist management select the suitable method. The area of in-plant modifications, though somewhat limited, is investigated.
CHAPTER I

INTRODUCTION

The objective of this thesis is to provide the textile industry of Georgia with suggestions, data, and general directions for the solution of water problems. The control and use of water has always been one of man's problems, but today it has been receiving much more attention because it is becoming increasingly critical. This situation is equally serious for both domestic and industrial users. The textile industry uses very large quantities of water and is vitally involved in all facets of its supply, use, and control.

This document is intended to serve as a guide to assist textile managements to understand better and to cope with water use and the associated problems. Specific engineering details are left to those responsible for designing facilities for individual mills. Technological and other information is presented to provide optimum wet processing and to be useful for solving problems which arise in process water supply and waste-water disposal.

This study was made for the state of Georgia, but the information presented should apply to the textile industry nation-wide. The background material for the thesis was provided by a Water Resources Research Project carried out with the Georgia textile industry (1). The information presented comes from personal observations and contacts with the industry as well as from the literature and scientific data in the field.
of textile water problems.

The bountiful supply of water, raw materials, and labor have been important factors in the rapid growth of water-using industries (pulp, paper, food, and textiles) in Georgia since the turn of the century. The textile industry in the United States began to develop in New England about 1800 (2). A major factor in its locating in New England was the available water to provide power and process water. Other factors such as market location, population density, transportation facilities, and national development greatly influenced the development of the industry in the Northeastern United States. The domination of textiles by New England continued until the South began to recover from its complete destruction by the War Between the States. Textile mills began to be constructed in the South primarily because the principle raw material, cotton, then used was grown in the South, but auxiliary reasons also existed.

The water supply of the Northeast had been of a quality desirable for textile processing, but this high quality water became depleted due to pollution. The Southeast, and in particular Georgia, has an abundant quantity of natural water provided by an annual rainfall of 50 inches (3). The low population density and the modest scale industrial development in the South made limited demands on the water supply. The textile industry has taken advantage of these conditions in the South and several mills have built on the major rivers and streams.

Today, textile manufacturing is Georgia's largest and oldest industry (4). Georgia is the third largest state in the production of textile products in the United States, exceeded only by North Carolina and
South Carolina (5). The industry in Georgia consists of some 370 textile mills employing over 103,000 persons (6). These mills are classified as:

- Fabric mills: 120
- Knitting mills: 49
- Floor covering mills: 121
- Yarn, thread, and cord mills: 70
- Miscellaneous mills: 32

A later survey indicates that the number of textile mills has increased to 383 (7). Of these mills about 100 are wet processing plants (8). The variety of mills in Georgia includes producers of fabric, yarn, hosiery, knitwear, tire cord, fibers, carpets, and specialty items.

Presently, the United States economy is expanding so rapidly, coupled with the Vietnam War, that the textile industry has a real challenge to provide the supply of products to meet the demand. The industry in Georgia has made large expenditures of capital for new buildings and equipment unmatched in the history of the industry (9). The tufting industry projects 100 percent production increase within the next five years (10). With the large increases in production, the water required to process these products will show a substantial increase unless new water using technology is improved. By all indications the quantity will be available, but the quality of the raw water may deteriorate if not protected (11).

To make this document of practical use for the managements of textile mills the various complex factors which confront the industry in water use and waste-water disposal are examined and analyzed. Wherever possible, specific avenues of approach for administrative and remedial action are suggested.

Five major areas of activities in which textile managements are
involved in water use and waste-water disposal are studied and discussed. These are: legal stipulations; water supply; water purification; waste-water treatment; and in-plant modifications for water conservation and waste control.

Recently, legislative bodies, both Federal and State, have formulated acts and laws to control and govern water pollution. Compliance with the laws passed is not the over riding reason for controlling pollution, but these laws do delineate the requirements which lead to standards which must be met to reduce pollution. A good comprehension of these laws and the responsibilities of the agencies that administer them is essential for management in order to formulate programs for water use and waste-water disposal.

Water supply, purification of process water, and the treatment of waste water all involve technical and engineering problems facing the industry. This thesis presents some methods available in each area and discusses the advantages of different methods of approaches open to management. Standards and other requirements are presented to assist in selection of methods.

A powerful tool for water conservation, waste control, and pollution abatement is in-plant modifications. This approach appears to have been somewhat overlooked or neglected. Examples from the literature and some in operation in Georgia are cited. Such modifications can make a large contribution to abating water pollution. Several methods of water reuse are suggested.
CHAPTER II

LAWS AND REGULATORY AGENCIES

General

To comprehend the treatment requirements for water and waste water, the current laws and rules that govern water and waste-water treatment must be understood. Many Federal and state agencies have responsibilities in regulating and assisting water users. To use their assistance and to comply with their standards, a knowledge of their functions is necessary. The rapid rate at which laws regulating water use and waste-water disposal have been passed reflects the growing importance of an understanding of the governmental control of water.

An extensive public information program on water shortage and water pollution control has been undertaken by both Federal and state agencies. These programs are designed to create local support for the actions to be taken by the governmental agencies. Water pollution has long been considered a local problem, but it affects a large area and population if it takes place in a large river basin. Because water pollution takes place in all sectors of the nation and affects interstate waters, the Federal government through the Federal Water Pollution Control Administration has assumed a nation-wide responsibility to control water pollution.

Water supply for domestic use and industrial use affects the health of the population, and health authorities have responsibility for the quality of water supplies. Quality of water is affected by pollution;
therefore, a constant cooperation exists between agencies controlling these two areas.

The laws and programs of the Federal and Georgia agencies controlling water supply and water pollution are discussed in the following sections.

Water Supply

Federal Government

Until 1965 both water supply and water pollution control were administered by a single division within the Public Health Service of the Department of Health, Education, and Welfare. Water pollution control has since been transferred to the Department of the Interior. Water supply is still a responsibility of the Public Health Service.

The Public Health Service (PHS) has the responsibility to assure safe drinking water for use on common carriers engaged in interstate commerce (12). The PHS first adopted drinking water standards to be applied to interstate commerce in 1914. The 1962 revision of the standards is accepted by all the States as minimum quality standards for public water supplies (13).

The PHS conducts research and makes tests to insure that the standards are adequate and are met. Public water supplies within a state are the responsibility of that state, but the PHS is involved with these supplies from the standpoint of public health, and they cooperate with the states in water supply control.

The standards as published contain the requirements of protecting water supplies. The method and frequency of sampling are set forth, and
the number of samples to be taken is set by the population served by the supply. The standards specify limits of impurities in drinking water as it reaches the ultimate consumer. These limits are (14, 15):

I. Bacteriological quality
   A. Not more than 10 percent in any month shall show the presence of the coliform group when using 5-10 ml. samples.
   B. Not more than 60 percent in any month shall show the presence of the coliform group when using 5-100 ml. samples.
   C. The arithmetic mean coliform density of all standard samples examined per month shall not exceed one per 100 ml. when using the membrane filter technique.

II. Physical quality
   A. Drinking water should contain no impurity which would cause offense to the sense of sight, taste, or smell.
   B. The following limits should not be exceeded
      1. Turbidity 5 units
      2. Color 15 units
      3. Threshold odor number 3

III. Chemical quality
   A. Chemical substances should not be present in excess of the listed concentrations where other more suitable supplies are or can be made available mg/l
      1. Alkyl benzene sulfanate 0.5
      2. Arsenic (As) 0.01
      3. Chloride (Cl) 250.0
      4. Copper (Cu) 1.0
      5. Carbon chloroform extract (CCE) 0.2
      6. Cyanide (CN) 0.01
      7. Fluoride (F) 0.9-1.7*
      8. Iron (Fe) 0.3
      9. Manganese (Mn) 0.05
      10. Nitrate (NO₃) 45.0
      11. Phenols 0.001
      12. Sulfate (SO₄) 250.0
      13. Total dissolved solids 500.0
      14. Zinc (Zn) 5.0
   *Dependent on temperature of the water and natural occurrence or fluoridation (supplementation of fluoride in drinking water for dental care).
B. Chemical substances present in excess of listed concentrations shall constitute grounds for rejection of the supply:

1. Arsenic (As)  0.05
2. Barium (Ba)  1.0
3. Cadmium (Cd)  0.01
4. Chromium (Cr)  0.05
5. Cyanide (CN)  0.2
6. Fluoride (F)  1.4-2.4*
7. Lead (Pb)  0.05
8. Selenium (Se)  0.01
9. Silver (Ag)  0.05

*Dependent on temperature of the water

The standards insure that the water will not be a health hazard to the user. The coliform limits insure that disease producing bacteria will not be present. The physical requirements have no physiological significance, except to produce attractive and palatable water. The limits set for chemicals serve to prevent poisonous substances as well as substances that produce taste, color, odor, or foam from contaminating the water. The addition of some chemicals for medical reasons (iodide or fluoride ions) to reduce non-contagious diseases constitutes mass medication, and is considered by some to be an unwarranted use of the water supply. Of course the addition of chlorine or chloramine for the disinfection of water has been used and accepted for many years.

Georgia Government

The policy of the State of Georgia is that the public and community water supplies of the State shall be utilized prudently to the maximum benefit of the people of the State (16). To accomplish this objective the Health Code designates the Board of Health of the State of Georgia as the agency to administer the provisions of Chapter 26 of the Code (Section 88-2601).

The Board of Health is granted powers and duties by the Code
(Section 88-2603). These include the following powers and duties:

1. to exercise general supervision over the administration and enforcement of the Chapter,
2. to establish standards of quality for water that will be distributed in water supply systems,
3. to establish such policies, requirements, and standards governing public or community water supply systems as it deems necessary,
4. to encourage, participate in, or conduct studies, investigations, research, and demonstrations relating to quality and purity of waters for public or community water supply systems,
5. to issue certificates covering the operation of public or community water supply systems,
6. to make investigations and inspections to insure compliance with this Chapter,
7. to advise, consult, and cooperate with other agencies of the State, political subdivisions thereof, other states, and the United States,
8. to collect and disseminate information relating to quality of water furnished to public and community water supply systems,
9. to adopt and promulgate rules and regulations applicable to public and community water supply systems,
10. to issue an order(s) directing any particular person(s) to secure such operating results for furnishing water for public and community water supply systems,
11. to exercise all incidental powers necessary to carry out the purposes of this Chapter.

To construct or operate any public water supply system a person(s) must first secure approval of the Board of Health (Section 88-2605). Once the approval has been granted a certificate is issued by the Board (Section 88-2606). Any holder of a certificate shall on request furnish information as may be required by the Board in the discharge of its duties (Section 88-2607). The Board has the right to inspect and investigate facilities that furnish water to the public (Section 88-2608). Information obtained by the Board is not admissible as evidence in a private action (Section 88-2609). The certificates and findings of the Board are no defense in civil actions (Section 88-2610). Any person who is aggrieved
or adversely affected by any final order or action of the Board has the
right to appeal to the Superior Court of Fulton County or county of his
residence or principal place of business within the State (Section 88-2611).
The Attorney General shall represent the Board in all actions in connec­
tion with this Chapter of the Code (Section 88-2612). The Board is
authorized to appoint officers to hold hearings on charges of violations
of this Chapter of the Code (Section 88-2613). Whenever the Board finds
that an emergency exists it may, without notice or hearing, issue an
order requiring action be taken to meet the emergency (Section 88-2614).
The Director of Public Health may make application to superior court for
an injunction to prevent a public health hazard (Section 88-2615). Any
person violating any provision of this Chapter shall be guilty of a mis­
demeanor (Section 88-2616). The Board is designated as the State agency
to receive and administer financial aid from the Federal Government or
other public or nonprofit source for purposes of water quality control or
any other purpose relating to public or community water supply systems
(Section 88-2618).

The Board of Health administers Chapter 26 of the Health Code
through the Water Supply Service of the Georgia Department of Public
Health. This Service reviews and approves plans for construction of
public water systems, and issues certificates for their operation (17). The Service operates a laboratory in Atlanta to perform water analysis
(18). Public water supplies are required to submit three samples per
month to the Service (19). The laboratory also analyzes samples for the
Division for Georgia Water Quality Control (20). The Service in
cooperation with the Division for Georgia Water Quality Control and the Georgia Water and Pollution Control Association sponsors and administers an intensive training program for water supply operators. The Georgia Department of Public Health cooperates with Georgia cities and towns in providing safe and adequate water supplies (21).

The Water Supply Service may require the textile industry to provide samples for any supply that served domestic use and may also require samples from industrial supplies. Failure to submit routine samples or samples that show contamination will bring action from the Service.

Any time water used by a mill is also used by the public for domestic purposes, the quality of the water must meet the drinking water standards.

Water Pollution Control

Federal Government

Water pollution has been a problem of this country for many years, but has only received serious Federal attention since the end of World War II. Prior to this time limited pollution control measures has been passed by Congress. These include the River and Harbor Act of 1899 (33 USC 407) which prohibited the addition of waste material other than those from city streets and sewers into navigable streams, and the Oil Pollution Act of 1924 (33 USC 431-437) which prohibited the addition of oil into the sea water.

Proposed Federal legislation was continued to be introduced into Congress from 1924, but no new laws were passed until 1948. Depression,
a world war, and actions of the States obviated Federal control of water pollution. In 1948, Congress passed the Federal Water Pollution Control Act, Public Law 80-845. This Act was a new approach to the solution of an old problem.

After several years of operation and administration of the Act, Congress passed Public Law 84-660, approved July 9, 1956, which with its amendments is the Federal Water Pollution Control Act (33 USC 466, et seq.). The amendments to Public Law 84-660 are Public Law 87-38, approved July 20, 1961, and Public Law 89-234, approved October 2, 1965. Two other Acts, Public Law 86-70 and Public Law 86-624, also amend sections of the basic law.

Public Law 89-234, "Water Quality Act of 1965" created within the Department of Health, Education, and Welfare a Federal Water Pollution Control Administration. An Assistant Secretary was designated to supervise and direct the head of the new Administration. By the creation of the new Administration, water pollution control was elevated from a division within the Public Health Service to a level parallel with the PHS. Since the Act was passed the Administration has been transferred from Health, Education, and Welfare to the Department of the Interior.

The provisions of the Federal Water Pollution Control Act (33 USC 466, et seq.) are:

1. it provides for the development of comprehensive programs for eliminating or reducing the pollution of interstate waters (Section 3),
2. it provides for cooperative activities by the states for the prevention and control of water pollution (Section 4),
3. it provides for research, investigation, training, and information relating to the causes, control, and prevention of water pollution (Section 5 & 6),
4. it provides for grants to state and interstate agencies to assist them to establish and maintain adequate measures for the prevention and control of water pollution (Section 7),

5. it authorizes the appropriation of money for grants to state, municipality, or interstate agency for use for sewage (Section 8),

6. a Water Pollution Control Advisory Board was established to advise, consult with, and make recommendations to the Secretary on matters relating to the Act (Section 9),

7. pollution of interstate or navigable waters shall be subject to abatement, and water quality criteria for these waters must be set (Section 10),

8. when pollution exist that violates the criteria, a conference will be held and recommendations to correct the situation will be made (Section 10),

9. if corrective action is not taken following a conference, then a hearing will be held and recommendations will be made (Section 10),

10. failure to comply with recommendations of a hearing will result in court action (Section 10),

11. Federal departments and agencies will cooperate in preventing or controlling pollution from Federal installations (Section 11).

The textile industry is affected in particular by two provisions of the Act. First, the textile industry must abate its pollution of interstate waters. An example of such a case is the recent conference held on the Chattahoochee River (July 14-15, 1966, Atlanta American Motor Hotel, Atlanta, Georgia). The report presenting the Federal Water Pollution Control Administration's case on Chattahoochee River pollution cited seven textile mills as major sources of pollution (22). Four of these mills are in Georgia. The report of the State of Georgia to the conference indicated that these four mills had made the necessary arrangements to abate their pollution (23).

Grants to municipalities are the second portion of the Act that is of definite concern to the textile industry. As industry cannot receive
these grants under the Act, the industry can only benefit by cooperating with a municipality which can receive a grant. An example is the grant to Trion, Georgia which will cooperate with Reigel Textile Corporation, Trion Division, in a joint treatment facility.

Georgia Government

The General Assembly of Georgia passed the Georgia Water Quality Control Act in its 1964 session. The Act (Ga. Laws 1964, p. 416) was approved March 11, 1964 and became effective July 1, 1964 (24). The policy declared in the Act (Section 3) is that the State shall utilize prudently the water resources of the state to the maximum benefit of the people. A reasonable degree of purity in the waters of the State must be restored and maintained, and where necessary, reasonable treatment of sewage, industrial wastes, and other wastes will be required prior to discharge into State waters.

The Act created the Division for Georgia Water Quality Control within the Department of Public Health (Section 4). The Division shall be supervised and directed by a State Water Quality Control Board, a nine-member board appointed by the Governor. The Board shall be composed of one representative selected from each of the following interests: Department of Public Health, to be chairman; soil and water conservation; recreation; municipal government; county government; commerce; industry; agriculture; and a member-at-large.

The Board shall select a qualified executive secretary who shall act as its administrative agency (Section 4). The Executive Secretary must be of good moral character and must be an engineer qualified in the field of sanitary engineering (Section 6).
It shall be unlawful to dispose of sewage, industrial wastes, or other wastes to Georgia's waters except in such a manner as to prescribe to the provisions of this Act (Section 10).

The remaining important provisions of the Act are as follows:

1. a permit is required to construct, install, or modify a waste disposal system (Section 10),
2. the Board shall supply technical information to and act to secure any person's cooperation in the reduction or elimination of water pollution (Section 11),
3. the Board may issue an order to bring about the reduction or elimination of pollution against any person who refuses to cooperate with the efforts of the Board (Section 11),
4. a person aggrieved or adversely affected by any action of the Board may request and obtain a hearing by filing a petition with the Board (Section 12 as amended by H.B. No. 335 (1966)),
5. after all administrative remedies have been exhausted, any person who is aggrieved by a final decision of the Board is entitled to judicial review (Section 13 as amended by H.B. No. 335 (1966)),
6. the Board shall hold hearings, adopt rules, establish standards, make investigations, and issue orders to control, abate, and prevent pollution of the waters of the State (Section 5),
7. the Board, after a public hearing, may institute appropriate actions to enforce the provisions of the Act by proper legal proceedings (Section 14),
8. the Board has authority to issue an order to be effective immediately if it deems an emergency exists. A hearing is required thereafter, as soon as possible (Section 20),
9. the Board may obtain an injunction from the appropriate superior court to cause a person to cease pollution (Section 21),
10. the State of Georgia is authorized to make grants, as funds are available, to any county, municipality, or combination of the same for construction of water pollution control projects. The Board shall administer these grants (Section 25 as amended by H.B. No. 52 (1966) and Section 26 as amended by H.B. No. 52 (1966) and Section 27),
11. violation of the Act is a misdemeanor and upon conviction is punishable as provided by law (Section 22).

The enforcement of the law is as follows:

1. investigate and determine if pollution of State waters exists,
2. if pollution exists seek cooperative abatement of the
pollution with the person(s) responsible,
3. if cooperative abatement is unsuccessful issue an order
to person(s) responsible to demonstrate and implement
abatement procedures to be taken,
4. if negative action received on first order, a second
order is issued requiring termination of pollution,
5. if termination action is not taken, then a public hearing
will be held,
6. after public hearing then court action shall be taken
to injoint further discharge of the pollution.

A flow chart of the action taken by the Georgia Water Quality
Control Board is given in figure one.

The Board has approved six rules to govern the operation and to
establish requirements for operation of waste-water discharges.

Rules Number One establishes the degree of waste-water treatment
required and the requirement for permits. All sewage shall receive at
least complete secondary treatment; and industrial waste and other wastes
shall receive treatment or corrective action so as to render the wastes
treated equivalent to complete secondary sewage treatment. Permits are
required for construction of waste treatment works and for operation of
these works upon completion.

Rule Number Two gives the details for submitting plans for the
construction of treatment works before a permit can be issued.

Rule Number Three sets the standards for waste effluents into
Georgia streams. Nothing can be added to Georgia streams that would
render them unsuitable for reasonable and necessary use.

Rule Number Four deals with marine toilet treatment devices re-
quired for boats operating on Georgia Waters.

Rule Number Five gives the Executive Secretary, Chairman, or Vice
Chairman of the Board authority to issue an order in an emergency case
such as inadvertent discharge of a toxic material into a stream.

Rule Number Six establishes the administrative procedures to be followed by the Board in the administration and enforcement of the Georgia Water Quality Control Act of 1964. The rule concerns Board meetings, hearings, notification of hearings, notices to file corrective plans, and statements of operation of the Division. This rule has recently been revised.

The Division for Georgia Water Quality Control prepared a report titled "Georgia's Water Quality Control Program" dated August, 1965. This report is a general statement of the activities and policies of the Division.

The Board holds a regular quarterly meeting in January, April, July, and October. These meetings are held in the State Health Building, Atlanta, Georgia convening at 11:00 am. The Board meetings are open to the public.

The Board submitted its First Annual Report 1965 to the Governor on February 1, 1966. The report described the program of the Board. A discussion of the quantity and quality of Georgia's Water resources was presented. The problems of water quality are stated and the textile industry was cited as the second largest source of organic industrial pollution. A summary of activities of the Board covers the operation of the Division.

Of particular interest to the textile industry is the training program. The program is a joint venture of the Board, the Water Supply Service of the Georgia Department of Public Health, and the Georgia Water and Pollution Control Association. Two schools of three days each were
Board Discovers Pollution

Board Seeks Cooperation

Polluter Complies

Polluter Refuses To Cooperate

Board Issues Order To Submit Plan

Polluter Submits Plan

Polluter Submits Ignores Order To Board

Polluter Ignores Plan

Board Approves Plan Issues Permit

Polluter Submits Plan

Polluter Submits Order To Board

Polluter Implements Plan

Polluter Appeals To Superior Court

Polluter Violates Permit

Polluter Appeals To Superior Court

Polluter Conditions Change

Polluter Violates Permit

Polluter Movements Or Revokes Permit

Polluter Complies

Polluter Ignores Appeals To Board

Polluter Ignores

Polluter Withdraws

Polluter Appeals To Board

Polluter Appeals To Superior Court

Polluter Injunction and/or Criminal Prosecution

Figure 1. Water Quality Control Flow Chart
held in 1965 to train water supply and waste disposal operators. Textile employees may attend these schools to improve their ability to operate water supply systems or waste disposal systems.

The report contains a section on Federal and State grants to construct waste treatment facilities. The appendix of the report contains a listing of the construction permits and operating permits issued by the Board in 1965.

The Board has published an "inventory of Municipal Sewage systems and Waste Treatment Plants in the State of Georgia". It has also published two technical manuals on waste stabilization ponds which are cited later in this thesis.

The Division is no doubt one of the most important governmental agencies with which the textile industry should and does cooperate. It is capable and willing to give technical assistance and advice.

Related Legislation

Federal Government

In addition to the above, the Federal government has many laws regarding water and waste-water treatment. Also, many Federal agencies perform functions related to water. Some of these Acts are briefly outlined, but the coverage is by no means complete.

The "Water Resources Research Act of 1964," Public Law 88-379, established State Water Resources Research Institutes and provided funds for water resources research. The Water Resources Center, Georgia Institute of Technology has been designated as the State Institute for Georgia, and the Center administers the water resources research program.
Several Acts have been passed to provide grants for construction of waste-water treatment facilities. These include the "Housing and Urban Development Act of 1965" (P.L. 89-117), the "Public Works and Economic Development Act of 1965" (P.L. 89-136), and the "Rural Water and Sanitary Facilities Act" (P.L. 89-240). An article describing these programs appeared in the Georgia Operator (25).

The "Water Resources Planning Act" (P.L. 89-80) was approved July 22, 1965. The Act provides for the optimum development of the Nation's natural resources through the coordinated planning of water and related land resources, through the establishment of a water resources council and river basin commissions, and by providing financial assistance to the States in order to increase State participation in such planning (26).

The Federal Water Program is advancing at a rapid rate. Legislation is presently being considered by Congress to increase the appropriations for construction grants for waste-water treatment facilities. The President outlined a broad program for controlling pollution and preserving natural and historical heritage in a message to Congress on February 23, 1966 (27).

Mr. Megregian, Federal Water Pollution Control Administration, has outlined the present Federal pollution control program and indicated future changes in a message presented to the Mid-West Section of the American Association of Textile Chemists and Colorists (28).

Georgia Government

More and more attention is being given comprehensive planning of water resources. The complex nature of water supply and waste-water...
disposal especially in urban areas requires better planning.

To provide planning the 1966 Georgia General Assembly passed a resolution (H. H. No. 297-698) to establish a Metropolitan Area Water Quality Control Commission. The Commission includes the Metropolitan Area of Fulton, DeKalb, Gwinnett, and Rockdale Counties of which the City of Atlanta is the major city. The resolution was signed as Act No. 158 of 1966.

The Commission was charged to study the desirability and feasibility of consolidating the efforts and management of the several water pollution control operations in the area and to develop recommendations concerning water quality control for the Metropolitan Area.

This particular Commission will have a direct effect on the future operations of the water pollution control facilities of the Metropolitan Area. Several textile mills operate within this area. Their methods of waste disposal may be affected by the products of the Commission's work.

The 1966 session of the General Assembly also passed a resolution (H.R. No. 39-55) to provide for the exemption from taxation of all facilities installed for the primary purpose of reducing air or water pollution. The resolution, a forward step in assisting industry, has been signed by the Governor and has become Act No. 112 of 1966. The Act is not a final answer since it is only an amendment to the Constitution of Georgia of 1945. The amendment must be voted on by the people in a general election. If the amendment is ratified, it shall become a part of the Constitution of the State and provisions stated therein shall become effective.

The amendment gives the General Assembly authority to provide for the exemption from any and all taxation any facilities installed or
constructed for the primary purpose of eliminating or reducing air or water pollution. The General Assembly is also authorized to determine how exemption will be granted and to prescribe the prerequisites to be met for exemption.

Even if the amendment is ratified, the General Assembly must act on the provisions stated before an exemption can be realized by the industry. The textile industry should consider this action in the next session of the Georgia General Assembly.
CHAPTER III

WATER SUPPLY

General

A water supply system includes all those facilities employed to deliver water of desired quality and quantity from its natural location to the point of use. In many cases, water is not of satisfactory quality and quantity in its natural location. Collection and purification facilities must be employed to render the water satisfactory.

Three alternatives exist for obtaining the necessary water for the plant. They are: buy water from a water supplier (usually a municipality); develop a water supply system; or a combination of the first two. Municipalities usually have a water system to supply water to the residents of the area. If the city is large enough and has sufficient water available, it may supply the textile mill with water. A small mill whose water consumption would be small compared to the total municipal consumption probably could more economically buy its water than develop an independent system.

A city may develop a water supply to furnish industrial water. An example of such is Dalton, Georgia, which under the guidance of excellent management has developed a water system capable of meeting the needs of the ever expanding tufting industry. Dalton has provided the water to support expansion of present companies and to attract new companies. The city is rewarded by the increase of revenue from its population increase and industrial growth. Many other Georgia cities supply water to textile mills.
When a city supply furnishes water to a mill, the mill must accept the quality of the water provided. Unless the mill can persuade the city to change the quality of the water supply to meet the special requirements of the mill, additional treatment may be required at the mill.

One must remember that the primary function of city systems is to supply suitable domestic water. Water for domestic consumption must meet drinking water standards set by public health authorities. The accepted standards in the United States are those designed by the Public Health Service, Department of Health, Education, and Welfare (29). Once a system becomes operative and supplies domestic water, it is obligated to continue the service. The standards for city water are minimum upper limits and in most cases the quality is better than these standards. Industrial water standards will be discussed later.

The second alternative is for the mill to develop its own supply. A self-owned supply allows the mill to set its own quality requirements and produce the quality of water desired. In the event the mill supply is used for domestic water then the quality must meet drinking water standards. As a safety measure the mill water should be potable. In the event the necessity to use the water for domestic purposes arises or in the event the water is consumed accidentally.

The third alternative is a joint supply for the mill and for the city. Such a venture may be carried out in several ways which are dependent upon the local situation. One arrangement is for the mill to use both city water and its own supply. Examples of the use of city water for domestic consumption in the mill and the use of mill supplied
water for wet processing exist throughout Georgia.

Regardless of the ownership of the water supply, the operation and construction of the system will be very similar in principle. The matter is usually settled on economical and political basis. A company owned supply that provides only process water for textiles may not be required to meet drinking water standards; therefore, causing some variation in treatment from city water.

Sources of Water

Two sources of water exist. They are surface water and ground water. Both are a result of the hydrologic cycle of water. The stages of the cycle of water include precipitation, percolation, runoff, and evaporation. The following diagram, figure two, illustrates the cycle of water.

In regions of high elevation above sea level the depth of subsurface water (ground water) usually makes the use of surface water, where available, more economical. In North Georgia the use of surface water predominates even though some deep wells are used. In South Georgia the use of deep wells predominates, but some surface supplies exist. The majority of the Georgia textile industry is located in North and Middle Georgia.

To determine the quantity of water available from a surface supply source the annual rates of flow must be known. These rates are available from the records of the U. S. Geological Survey (30). The Survey has gaging stations on all streams throughout Georgia and they collect and record substantial data on stream flows. These records are very good and useful.
Figure 2. The Water Cycle
If the low flow is sufficient to meet the demands of the mill plus the required minimum stream flow, then the stream will serve as a supply without modification. If the average annual flow is sufficient, but the low flow is not sufficient to meet requirements, the source can generally be used if sufficient storage is provided. If the average annual flow will not meet the demand requirements, the source cannot be used without another source or an additional source can be located.

Ground water can be obtained in Georgia above the fall line (Columbus to Macon to Augusta), but it generally has proven uneconomical and unsatisfactory as a major source in North Georgia. Below the fall line ground water can be removed from deep wells at rates usually up to 4,000 gallons per minute without affecting the source (31).

Ground water supplies have a collection basin or stream much like surface water except that it is underground. The depth of the available water will determine the method of collection. A natural spring may be collected similar to surface water, namely with an intake and pump. Water that is far below the surface will require a deep well and a pump and storage system to collect and deliver it.

A report on the available water sources of Georgia has been published by the Industrial Development Division of the Georgia Institute of Technology (32). The report is designed to provide a ready reference on Georgia's water resources. The quality of the water at various locations throughout Georgia is given. Water sources should be a prime factor when considering a possible location of a textile wet processing mill. This report will be helpful when determining plant location.
Collection Works

Water collection systems, like most other engineering works, should be designed and developed by experienced and capable people. The type of collection system used will depend upon the source.

Surface water is collected through an intake structure which has a screen to remove large solids. Since the source of water is frequently at a low elevation in the area, the water must be pumped to the system.

When a reservoir is used as a source, the intake should be located away from the shoreline to provide draw off at different depths to obtain the best quality of water stored in the reservoir. Reservoirs do effect the quality of the water stored in them. The effect may be either an improvement due to settling or a degradation due to microorganism action. Therefore, it is important to operate a reservoir so that the highest quality water can be withdrawn.

When the source is a flowing stream, generally the intake is placed near one bank, and is so constructed that water can be drawn at low flow. The requirement of drawing at different depths depends only on the stream flow heights and little can be gained by quality due to depth in a freely flowing stream. Pumps should be placed at an elevation to provide protection of the equipment from high water.

A deep well is generally the most successful method of removing large quantities of water from ground supplies. These wells should have a water tight casing extending into the aquifer. They should also be protected from surface runoff by a drainage system, and they should be sealed at the top.
Deep well discharges are rated in gallons per minute because pumps are conventionally rated in gallons per minute. Deep wells in South Georgia commonly yield 1,000 gallons per minute.

The drilling of a deep well that will supply the required quantity of water is a major undertaking. Even though the water is available below the surface, it may be difficult to obtain it. The type of soil, mud, and rock present affects the drilling and operation of a well. While drilling is in process many obstacles exist. The drill bit may be lodged or the drill shaft may break. Recovery of broken bits and shafts from several hundred feet below the surface is a difficult task. In some cases, it may become necessary to begin to drill another well if the problem in the first well cannot be corrected.

Once the well has been drilled it must be properly cased. The pump must be placed in the well and the drive motor connected to the pump. The completed well must be developed and tested. Development of a well consists of intermittent pumping out of the well and then pumping into the well. This operation breaks up the aquifer and removes the small particles that would prevent proper flow of the well. An improperly drilled and equipped well can present problems that are not easily corrected. One major problem of wells is that of sand being pumped out with the water.

It would be wise to employ a competent well drilling company to furnish a deep well. Codes and rules exist for the procedure that must be followed in providing a deep well water supply. The reputation and integrity of the well drilling company will be reflected by the quality of well provided.
Water Impurities And Quality Requirements

The sources of water will contain impurities because no natural water supply consists of chemically pure water. The character and amounts of impurities vary for different water sources. They may also vary over a wide range for different seasons and with the amount of rainfall.

The impurities that are present in water sources may be grouped as:

1. dissolved mineral matter
2. dissolved gases
3. turbidity
4. color and organic matter
5. tastes and odors
6. microorganisms

Surface supplies will generally contain each of the above classes of impurities. Ground waters will generally be much purer than surface waters, but frequently contain higher concentrations of dissolved minerals which cause the condition of hard water.

The need for treatment depends upon the impurities present and the use of the water. Industrial uses of water may be classified as follows:

1. cooling
2. processing (entering into or contacting products manufactured)
3. power generation
4. sanitary services
5. fire protection
6. miscellaneous (air conditioning, housekeeping)

The textile industry generally uses water for processing (desizing, scouring, bleaching, dyeing, and finishing); for sanitary services (domestic services for employees); fire protection; and for air conditioning, cooling, and steam.
The type of impurities in water will generally affect each of these uses except fire protection, which hopefully, will not require a large volume of water. The type of impurities will be discussed in the order in which they have been listed.

All natural water supplies contain dissolved mineral matter. The most abundant mineral constituents are the bicarbonates, sulfates, and chlorides of calcium, magnesium, and sodium.

Calcium bicarbonate exists in water that has made contact with calcium carbonate (limestone, marble, chalk, calcite, dolomite) in the presence of carbon dioxide. The other minerals dissolve into the water in some similar fashion. In South Georgia the aquifers are generally limestone and, therefore, produce high mineral content water; especially, calcium bicarbonate.

Hardness of water is due to calcium and magnesium content. Hardness is expressed in terms of parts per million of calcium compounds. The solubility of calcium and magnesium compounds usually decrease as the temperature increases. Water that is to be used in processes or equipment that involves heat should not be hard because the minerals will be deposited in the processing or on the equipment. Hardness from metal ions which react with soap to form insoluble compounds which form deposits and also decrease the effectiveness of the soap.

Other minerals in water such as iron and manganese will cause difficulty in processing. Iron will cause water to have a red color. Aeration will precipitate the iron. Manganese in water will precipitate at high pH values forming a gray-black deposit. The red or gray-black deposits are undesirable on finished fabric or yarn, and it is thus highly
important that the minerals which cause color deposits on fabric be removed, as well as hardness.

The dissolved gases present in Georgia water are carbon dioxide, oxygen, and nitrogen. Carbon dioxide affects the pH of water, affects the mineral content, and is corrosive. Oxygen is exceedingly active and causes corrosion. Nitrogen is inert and is relatively unimportant in water treatment.

Turbidity and sediment are finely divided, insoluble impurities. These suspended impurities may be inorganic matter, such as clay, silt, silica, and calcium carbonate; or they may be organic, such as vegetable matter, animal matter, oils, fats, and microorganisms. This suspended matter usually mars the clarity of water and is called turbidity. Turbidity is undesirable in textile processing because the particles may collect on the product.

Color and organic matter are found mostly in surface water. Color may be caused by minerals (iron, manganese) or organic matter. Color is generally objectionable in textile processing because it would stain the products. Color is also undesirable for aesthetic reasons. Organic matter which produces color is also objectionable.

Most odors and tastes are caused by organic matter. They are objectionable because of the presence of the compounds that cause them. Textile materials will absorb odors and render the product undesirable.

Microorganisms are present in all water that is exposed to the atmosphere. Generally, deep well water is free of microorganisms unless it is contaminated by surface water seeping into the well. Microorganisms
are objectionable because they produce color, turbidity, taste, and stains. Some of them have the ability to decompose cellulose and discolor or stain cellulose.

The impurities in water must be removed for the reasons discussed. Purification treatment of water is accomplished by a set of unit operations which are specifically designed to remove the impurities present.

Before the treatment plant is built and during its operation the types of impurities and their concentration must be determined. The techniques of Standard Methods are the basis of most water and waste-water analyses (33). When the concentrations of impurities are determined the type and scope of treatment to be used can be determined. Textile wet processing water should be free from turbidity, color, iron, manganese, hardness, and organic matter and it should not be corrosive.

Standards of water quality for industrial water have been attempted by several organizations, but successful standards have as yet not been established because of the variability of process requirements. Some of the attempts have set general standards for industry groups. Those for the textile industry appear in table one (34).

As a general rule municipal water supplies are of such a quality that with the exception of hardness, they can be used by textile wet processing plants. Plants that produce bleached white goods cannot tolerate any iron or manganese. These minerals are removed when hardness is removed with iron exchangers.
Table 1. Water Standards

<table>
<thead>
<tr>
<th>Type of Impurity</th>
<th>Permissible Upper Limit in ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity as SiO₂</td>
<td>1.50</td>
</tr>
<tr>
<td>Color in platinum units</td>
<td>5.00</td>
</tr>
<tr>
<td>Total hardness as CaCO₃</td>
<td>10.00 - 15.00</td>
</tr>
<tr>
<td>Manganese as Mn</td>
<td>0.01 - 0.02</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>200</td>
</tr>
<tr>
<td>Aluminum as Al</td>
<td>0.25 - 0.40</td>
</tr>
<tr>
<td>Heavy metals</td>
<td>0.01</td>
</tr>
<tr>
<td>Silica as SiO₂</td>
<td>10.00</td>
</tr>
<tr>
<td>Alkalinity as CaCO₃</td>
<td>75 - 100</td>
</tr>
<tr>
<td>Iron as Fe</td>
<td>0.01 - 0.05</td>
</tr>
</tbody>
</table>
CHAPTER IV
WATER PURIFICATION WORKS

Surface Water Supplies

Surface water supplies will generally contain impurities of six classes (dissolved mineral matter; dissolved gases; turbidity, suspended matter; color and organic matter; tastes and odors; and microorganisms). These impurities must be removed before the water can be used for textile wet processing. It is the function of the purification works to remove them.

Conventional water treatment consists of five basic unit operations; addition of chemicals, rapid mix, flocculation, sedimentation, and filtration. The following diagram, figure three, indicates an arrangement to provide good water.

The primary objective of conventional treatment is to remove suspended and dispersed matter which causes turbidity and color. Dissolved mineral matter (hardness) will be discussed separately. Microorganisms will be removed to some degree with conventional treatment, but the addition of chlorine will kill those that remain. Once organic matter and microorganisms are removed, objectional tastes and odors will generally disappear.

Coagulation

Coagulation will reduce the concentrations of turbidity, color, and organic matter to limits that can be tolerated. Aluminum sulfate
(alum) is the most extensively used coagulant for water treatment. The common form of alum used is Al₂(SO₄)₃·18H₂O. It may be fed into the water either in dry form or in solution. Generally the water should be slightly alkaline and it may be necessary to feed caustic soda (NaOH) with the alum. In alkaline water aluminum hydroxide (Al(OH)₃) is formed. This hydroxide is insoluble in water and is called floe.

Iron compounds are used as coagulants by some water treatment plants. Both ferrous and ferric salts are used which produce insoluble ferric hydroxide as coagulant. The advantage of iron coagulants over alum is the wide range of pH values over which the iron compounds precipitate. The disadvantage is that iron compounds will produce spots on fabric or yarn if they are not completely removed from mill water systems. A rapid mix process follows hydroxide addition.

Rapid Mix

Several methods are used to provide rapid mixing of the chemicals with the water. Mechanical agitation by a motor-driven paddle in a tank is one of the more common ways. The time required for adequate mixing is from 3 to 30 seconds. The design of a high-speed mechanical mixer is shown in figure four.

Other methods include passing the water through flumes or conduits fitted with baffles and conduits that impose high velocity and turbulence.

Flocculation

Following the rapid mixer the water passes to the flocculator. It is somewhat similar to the rapid mixing step except that it is slowly mixed. Such treatment promotes the development of large, dense floc which settles rapidly. Modern plants are equipped with motor-driven flocculating
Figure 4. High-Speed Mechanical Mixer
Figure 5. Mechanical Flocculation Tank
equipment as shown in figure five. The time required for flocculation ranges from 20 minutes to one hour.

Some plants are designed to provide flocculation by the use of "around-the-end" or "up-and-down" baffles. Figure six shows around-the-end type in which the water flows in a narrow, but deep passage with 180 degree turns. Figure seven shows an up-and-down type in which the water must travel alternately over and under baffles.

Sedimentation

After flocculation the water flows to settling basins. They are usually rectangular tanks designed for straight flow, but they may be square or circular. A minimum of two hours of detention is required for conventional settling basins.

The deposits formed by the settling floc must be removed, either periodically or continuously. If deposits are allowed to build up, they will reduce the settling capacity of the basin. Decomposition of the organic matter in the deposits will result in a reduction of the efficiency of the tank.

Continuous removal has the advantage of allowing constant operation of a basin. With periodic cleaning, a basin must be taken out of service; and cleaned by manual methods. Sludge removed from the basin is generally returned to the stream. Periodic removal also required the discharge of a large volume of sludge at one time while continuous permits discharge of only a small volume continually.

Continuous removal is achieved by the use of a mechanically operated rake which moves the deposited sludge to a sump where it is drawn off. Figure eight shows a settling basin equipped with continuous sludge removal.
Figure 6. Around-the-End Flocculator

Figure 7. Up-and-Down Flocculator
Figure 8. Settling Basin
The system outlined is that used by most municipal water systems using surface water as a source. Some surface water may contain only small concentrations of impurities and will require only filtration. Generally filtration follows sedimentation.

Rapid-flow Coagulation

A new type of coagulation system has been developed to prepare water for filtration. The system is known by various names in the trade. Permutit uses the 'Spaulding Precipitator' and Infilco uses an 'Accelator'. All are really rapid-flow clarification tanks. They are a combination of chemical feed, mixing, flocculation, settling in one unit.

The Spaulding Precipitator by the Permutit Company as shown in figure nine operates on the principle of upward-flow coagulation and clarification (35, 36). The water is fed into the center inverted cone into which the chemicals are also fed. Mixing is provided by the mechanical agitation. The water then passes through ports at the bottom of the cone, and then rises through a predetermined depth of previously formed sludge in the outer upright cone. The cone is so designed that the velocity of the water decreases as it rises. The decreasing vertical velocity permits the water to reach a plane at which its velocity will leave the sludge behind. The velocity of the water and the height of the sludge blanket is controlled by the rate of flow through the plant. The clear water is drawn off at the trough around the outside circumference of the tank. The clear water is then ready for filtration. Excess sludge is drawn off from the bottom of the tank through a drain.

The intimate contact of the water with the precipitate assures completeness of reaction with maximum absorption and retention of
Figure 9. Spaulding Precipitator
suspended matter that ordinarily is not obtainable with standard sub-
sidence basins.

The Accelator by Infilco Incorporated is based on the same rapid-
flow principle, but is different in design and operation (37). Figure
10 shows an Accelator. The water and chemicals are added to a thick con-
centration of precipitated sludge near the bottom of the tank. An
impeller provides mixing of the raw water and chemicals. From the pri-
mary mixing zone the water rises to the secondary mixing zone to which
the sludge is retained because of the mixing. The water then flows down-
ward into the outer section of much larger diameter which is free of turbu-
ulence. The clear water then flows up and is removed through a trough
around the outside circumference. The up flow of the water permits the
settling of the floc in the compartment. Some of the sludge is collected
by the concentrator compartment, where it is continuously removed, but
a larger portion passes through a return back into the primary mixing
zone.

The rapid-flow coagulator requires about 50 to 75 percent less
retention time than the conventional treatment. The area required for
the equipment is less and the initial cost and operating cost are less.
The quality of the water produced is as good if not better than conven-
tional treatment. One such installation has been observed by the author.
The Company had been experiencing some difficulty with obtaining large
floc and some of the small floc was being carried over into the outlet
trough. However, these difficulties are being corrected and this equip-
ment is expected to perform very well at less costs than conventional
coagulation.
The decision to use either the conventional or the rapid-flow type of clarification basins should be carefully weighed. The conventional design will produce more uniform water under widely varying concentrations of turbidity because of its longer detention time. The operation is less critical than rapid-flow units. However, the cost of rapid-flow units is less and also the removal of excess sludge is usually much easier and less complex with the rapid-flow units.

**Filtration**

The two satisfactory types of filters used are the gravity filter and the pressure filter. Sand is most commonly used as a filter bed in both type units. However, anthracite coal and other materials have been used. One special type of pressure filter using porous tubes is usually coated with diatomaceous earth, diatomite, or other filter aid.

Gravity type rapid sand filters are illustrated in figure 11. They consist of a bed of 24 to 36 inches of sand resting on a bed of graded stone. Below the stone is an underdrain system which collects the filtered water and distributes the backwash water.

The pretreated water enters the filter above the sand bed, and flows through the sand leaving any impurities on the surface of or trapped between the granules of sand. The water moves through the stone and is collected by the underdrain and passes on to a clear well or filtered water basin.

The material collected on the sand bed must be removed from the sand periodically to maintain an efficient operating filter. A filter is cleaned by reversing the flow in the filtering process; that is, by discharging water upward through the underdrains and through the sand beds.
Figure 11. Rapid Sand Filter

A. Water Inlet
B. Drain
C. Water Outlet
D. Sand Bed
E. Gravel
F. Underdrain
Of course the filter is taken out of operation during the backwashing process and the backwash water is collected in the wash-water throats and is passed into a sewer.

Pressure filters function in a somewhat similar manner as gravity is forced through the bed under pressure. This type of filter is most commonly used when the water system is operated under pressure, such as on city water mains, thereby obviating repumping. This type filter has been used extensively with swimming pools. The author observed the use of vertical pressure filters by one Georgia textile mill to reduce city water to zero turbidity.

**Dissolved Mineral Matter**

The treatment thus far described removes turbidity, suspended matter; color and organic matter; and microorganisms from the raw water. Remaining are the dissolved mineral matter and the dissolved gases. These are discussed separately because of their importance and also because of the variety of methods available for removing them.

The dissolved minerals present in water in concentrations that generally require their removal are iron, manganese, calcium, and magnesium. The presence of calcium and magnesium salts is commonly referred to as "hardness." The presence of hardness (calcium and magnesium); iron; and manganese are cited as problems of the Georgia textile industry (38).

Hardness is classified as either carbonate (temporary) or non-carbonate (permanent) depending on the anion present. Carbonate hardness has the bicarbonate ion present in the water with the calcium and magnesium ions. Bicarbonate hardness is commonly called temporary
because it can be removed by simply boiling the water. The reaction is:

$$\text{Ca}(\text{HCO}_3)_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O} + \text{CO}_2$$

In the reaction the heat drives off carbon dioxide ($\text{CO}_2$) from the bicarbonate ion and converts the calcium bicarbonate ($\text{Ca}(\text{HCO}_3)_2$) to the insoluble calcium carbonate ($\text{CaCO}_3$). Boiling of water has not proven economical as a method of softening large volumes of water, but with the conversion of sea water to fresh water it may be so in the future.

Non-carbonate hardness, commonly called permanent, is due to the presence of calcium or magnesium as sulfates, chlorides, or nitrates. This type hardness cannot be removed by boiling the water; a chemical treatment is required.

Table two gives a summary of the types of hardness.

**Table 2. Types of Hardness**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Carbonate Hardness</th>
<th>Non-carbonate Hardness*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Hardness</td>
<td>Calcium bicarbonate</td>
<td>Calcium sulfate</td>
</tr>
<tr>
<td></td>
<td>Calcium carbonate</td>
<td>Calcium chloride</td>
</tr>
<tr>
<td>Magnesium Hardness</td>
<td>Magnesium bicarbonate</td>
<td>Magnesium sulfate</td>
</tr>
<tr>
<td></td>
<td>Magnesium carbonate</td>
<td>Magnesium chloride</td>
</tr>
</tbody>
</table>

*Non-carbonate hardness due to nitrates is usually minor in quantity.

Three methods of hardness removal are practiced by the textile industry. They are by the addition of chemicals that remove hardness, by ion exchangers, and by the addition of chemicals that sequester the hardness.

The first, softening by the addition of chemicals that remove
hardness, uses lime and soda ash. Lime is calcium oxide (CaO) and when water is added it becomes calcium hydroxide (Ca(OH)_2). The hydroxide has become known as lime since the addition of either the oxide or the hydroxide will produce the same effect, but here the hydroxide is used in all reactions.

When calcium hydroxide is added to water several reactions take place depending on the type hardness present. Calcium bicarbonate (Ca(HCO_3)_2) is converted to calcium carbonate (CaCO_3) which is relatively insoluble, approximately 50 ppm, and is removed by settling and filtration. The reaction is:

\[ \text{Ca(HCO}_3\text{)}_2 + \text{Ca(OH)}_2 \rightarrow 2\text{CaCO}_3 + 2\text{H}_2\text{O} \]

Magnesium bicarbonate (Mg(HCO_3)_2) is also converted to magnesium carbonate (MgCO_3) by the addition of calcium hydroxide (Ca(OH)_2), but the carbonate of magnesium is soluble. The reaction is:

\[ \text{Mg(HCO}_3\text{)}_2 + \text{Ca(OH)}_2 \rightarrow \text{MgCO}_3 + \text{CaCO}_3 + \text{H}_2\text{O} \]

Additional calcium hydroxide will react with the magnesium carbonate to produce insoluble magnesium hydroxide (Mg(OH)_2). The reaction is:

\[ \text{MgCO}_3 + \text{Ca(OH)}_2 \rightarrow \text{Mg(OH)}_2 + \text{CaCO}_3 \]

As seen from these two reactions, two equivalents of Ca(OH)_2 are used to remove magnesium bicarbonate. Magnesium sulfate (MgSO_4) and magnesium chloride (MgCl_2) are also converted to magnesium hydroxide by addition of one equivalent of Ca(OH)_2. The reactions are:

\[ \text{MgSO}_4 + \text{Ca(OH)}_2 \rightarrow \text{Mg(OH)}_2 + \text{CaSO}_4 \]

\[ \text{MgCl}_2 + \text{Ca(OH)}_2 \rightarrow \text{Mg(OH)}_2 + \text{CaCl}_2 \]
Calcium sulfate (CaSO₄) and calcium chloride (CaCl₂) are produced by Ca(OH)₂ removal of magnesium non-carbonate hardness. Of course, these two compounds are also hardness.

The calcium non-carbonate hardness can be removed by addition of soda ash (Na₂CO₃). The reactions are:

\[
\begin{align*}
\text{CaSO}_4 + \text{Na}_2\text{CO}_3 & \rightarrow \text{CaCO}_3 + \text{Na}_2\text{SO}_4 \\
\text{CaCl}_2 + \text{Na}_2\text{CO}_3 & \rightarrow \text{CaCO}_3 + 2\text{NaCl}
\end{align*}
\]

Since this type of softening requires the addition of calcium salts, one cause of hardness, proper control to assure the addition of the correct amounts of chemicals must be taken to prevent the presence of hardness upon completion of the operation. Table three summarizes the chemicals and amounts required for the removal of each type of hardness.

**Table 3. Chemical Requirements for Softening**

<table>
<thead>
<tr>
<th>Type of Hardness</th>
<th>Chemicals</th>
<th>Amount</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbonate</td>
<td>None</td>
<td>None</td>
<td>CaCO₃</td>
</tr>
<tr>
<td>Calcium bicarbonate</td>
<td>Lime</td>
<td>1 equivalent</td>
<td>CaCO₃</td>
</tr>
<tr>
<td>Calcium sulfate</td>
<td>Soda ash</td>
<td>1 equivalent</td>
<td>CaCO₃</td>
</tr>
<tr>
<td>Calcium chloride</td>
<td>Soda ash</td>
<td>1 equivalent</td>
<td>CaCO₃</td>
</tr>
<tr>
<td>Magnesium carbonate</td>
<td>Lime</td>
<td>1 equivalent</td>
<td>CaCO₃ Mg(OH)₂</td>
</tr>
<tr>
<td>Magnesium bicarbonate</td>
<td>Lime</td>
<td>2 equivalent</td>
<td>CaCO₃ Mg(OH)₂</td>
</tr>
<tr>
<td>Magnesium sulfate</td>
<td>Lime/Soda ash</td>
<td>1 equivalent ea.</td>
<td>CaCO₃ Mg(OH)₂</td>
</tr>
<tr>
<td>Magnesium chloride</td>
<td>Lime/Soda ash</td>
<td>1 equivalent ea.</td>
<td>CaCO₃ Mg(OH)₂</td>
</tr>
</tbody>
</table>
The process can be carried out either separately or in combination with coagulation of the water. When carried out with coagulation the calcium hydroxide and/or soda ash are added with the coagulant and the soda softening. The process is only used where the water is very hard since zero hardness is not the end product. The process may also be carried out by heating the water, called hot-process softening. The solubility of calcium carbonate and magnesium hydroxide decreases as the temperature increases. This process has its main application as treatment for boiler feed water.

The second method of softening is ion exchange. The process is carried out by the use of an ion exchanger. An ion exchanger is a giant molecule which consists of a network of covalently bonded atoms some of which have either positive or negative charges (usually one or the other). Figure 12 gives an example of a cation exchanger. Many of these molecules are packed together to form an ion exchange resin. The example cited has negative charges on the covalent molecules. The molecule is very porous and the pores are filled with water containing positive charged ions to give an electrically neutral system. When a solution containing a salt (ionized positive and negative charged ions) is passed through the resin, the positive ions in the solution exchange with the positive ions in the resin. The reaction of a common system is:

\[ \text{Ca}^{++} + 2\text{Na}^+\text{R}^- \rightarrow \text{Ca}^{++}(\text{R}^-)_2 + 2\text{Na}^+ \]

By proper selection of ions in the resin, water can be produced to contain only those ions desired.

Anion exchangers operate similarly to cation exchangers except that the covalent network carries positive charged ions and the mobile exchangeable ions are negative.
Figure 12. Cation Exchanger Molecule
The first ion exchange resins were naturally occurring compounds. They were given the name "Zeolite." Sodium zeolite softening of water has been used for many years. Hydrogen ion exchangers are commonly used followed by an anion exchanger with hydroxide as the mobile ion to produce water free of any mineral matter.

Of course, once all the mobile ions have been replaced (exchanged), the system can no longer remove the undesirable ions. The ion exchanging medium can be rejuvenated by regeneration. In the case of a sodium ion exchanger a concentrated salt solution (brine) is passed through the resin to exchange the removed ions with sodium. Figure 13 is a diagram of an ion exchanger.

Raw water enters at the top and flows through the resin where exchange takes place. For softening, the calcium and magnesium ions are replaced by sodium or hydrogen ions. In addition, other heavy metal ions are also removed. Most textile mills use sodium exchangers since sodium ions have no adverse effect in wet-processing operations, but the hydrogen ion might. Also the brine solution is cheaper and easier to handle. Regeneration takes place by closing the water inlet and outlet valves and introducing the brine solution at the bottom and passing the discharge to a drain.

It has been shown that improved regeneration can be obtained by the use of a counterflow system (39). By passing the regeneration solution up through the resin not only can the removed ions be replaced, but trapped sediment can also be removed. Resins are stable and can be used repeatedly unless they become contaminated with impurities that restrict the resin's function. Figure 14 illustrates how counterflow
Figure 13. Ion Exchanger

Figure 14. Ion Exchanger With Counterflow Regeneration
regeneration takes place.

The zeolites have been replaced by synthetic resins that are more effective repeatedly at high flow rates. Resins have been developed that resist contamination by impurities (40).

The third method of controlling hardness is by the use of chemicals that form complexes that tie up, sequester, the calcium and magnesium ions. Certain phosphates are used to sequester calcium and magnesium; they are also effective for iron and manganese. One of these well known compounds is Calgon (Registered Trade Mark U.S. Patent Office). It is stated that Calgon completely softens water and renders hardness-forming salts harmless by complexing them (41).

Iron and manganese can be removed from water by settling and filtration if the water receives sufficient aeration. Many sand filters throughout Georgia have a black coating of manganese dioxide on the surface of the sand bed. The coating acts as a catalysts to remove additional manganese.

If iron and manganese are present after filtration, they can be removed by ion exchangers or tied up by the complexing chemicals. Control of iron and manganese in water is very important in textile wet processing. The use of chlorine to oxidize the soluble forms of these ions assists in removing them by conventional water treatment. This addition of chlorine has become known as prechlorination and is very helpful in forming insoluble iron and manganese compounds. As direct and desirable as their removal seems, they still are present in some systems. Red and black stains on fabric and process equipment cause very undesirable appearance. Every consideration should be taken to see that they are not present.
Ground Water Supplies

Usually the only impurities present in ground water are dissolved mineral, but some sources contain quantities of sand or silica.

The removal of mineral content has been explained in the discussion of surface water purification. The most commonly used method is ion exchangers.

Sand can be removed by filtering and settling. Silica can be removed by the processing for mineral content removal. Ion exchangers are used to remove silica.

Chlorination

Control of microorganisms in water has been practiced for many years by the addition of chlorine to water. Drinking water must be free of algae growth and bacteria. Boiler feedwater, cooling water, and textile processing water also should be free of these organisms.

Chlorination usually consists of adding chlorine gas to the water by means of a chlorinator, which is an instrument specially designed to regulate, meter, and inject the chlorine gas into the water supply. Chlorine is a poisonous gas and must be handled with extreme care. Accidental addition of excessive chlorine to water causes inconvenience, but imparts so much odor and taste that it is completely unsuitable for consumption and will not be consumed.

Chlorination can also be accomplished by the addition of chlorine containing compounds to water. The equipment required is less expensive than the gas chlorinators, but the compounds are more expensive than pure chlorine.
Miscellaneous Treatments

Activated carbon can be used to remove taste, odor, and color if these constitute a problem. Activated carbon is used where coagulation and settling are employed. The carbon is added with the coagulating chemicals. The carbon has the ability to adsorb the odor and taste producing matter and also color producing matter. The carbon is removed by settling and filtration.

Hydrogen sulfide gas is present in some ground waters, commonly called sulfur water. It may also be present in surface water as a result of pollution. If the content is low, aeration and conventional treatment will remove the gas. If the content is high, carbon dioxide gas is added, possibly as flue gases; or some other acid may be added to lower the pH and thereby, liberate the $H_2S$ gas.
CHAPTER V

WASTE-WATER TREATMENT

General

Waste materials are removed from their point of origin by a sewer system. This waste-water must be discharged, with or without treatment, to a receiving stream or body of water. In the past, disposal without treatment has been widely practiced and it was quite acceptable. Now with increased industrial activities and with an ever increasing population, waste-water disposal without treatment has exceeded or soon will exceed the assimilative capacity of the nation's streams. To prevent pollution of rivers, lakes, and coastal waters, the wastes must be completely removed or partially removed from the transporting water before discharge of the waste-water. Because waste-water treatment is no longer a questionable requirement, but a necessary requirement, the present objective should be to develop and provide the most economical and efficient method of treatment.

The required degree of treatment of waste-water depends upon the nature of impurities in the water and their concentration, upon the nature and flow of the receiving water; and upon the purposes the receiving water will later serve. The requirement of the Water Quality Act of 1965 that criteria be set for interstate and navigative waters establishes limits for impurities in waste-water discharged to these receiving waters. Limits of this type are referred to as effluent standards.
More commonly preferred are the so-called stream standards which state that certain quality conditions must exist in the stream. Exactly how a set of conditions are maintained in a stream without limiting what is added to the stream is not clear.

Water control agencies in the past have set treatment requirements for BOD* removal of 90 to 95 per cent. For domestic sewage a percentage removal approximates a constant effluent, since the influent is relatively constant. For industrial wastes, which are not constant for each unit within an industry group much less among different industry groups, percentage removals do not seem valid. As the concentration of impurities doubles in the influent waste-water, by removing a constant percentage, the concentration of impurities remaining after treatment double.

Possibly, new standards will require that water contain a limited amount of BOD before it is discharged. Even though standards of this type may be better than others, those finally set will have to be met in the future.

This chapter outlines the development of treatment requirements and the methods for treatment.

Sources Of Waste Water

Textile wet-processing consists of many separate operations which produce waste water. Each operation produces a different type waste water.

*Biochemical Oxygen Demand, a measure of the rate and extent of oxygen depletion by organic waste matter from a biochemical environment similar to that in nature. Samples of waste water are incubated in the presence of suitable microorganisms and nutrients for five days at 20°C., and then oxygen consumption is measured.
The character of the waste from each process depends upon the type of fiber being processed and the chemicals used in the process.

**Cotton Wet Processing**

The wet processing of cotton can and usually does consist of: desizing, scouring, bleaching, mercerizing, dyeing, printing, and finishing. The end use of the produce determines the processes through which the product will pass. Washing and rinsing are a vital part of several of the above processes. They are required to remove the natural impurities and chemicals produced by and added in the process.

**Desizing.** Most cotton fabric must be desized. Size is a compound that is applied to warp yarn to aid weaving. It must be removed before wet processing.

The waste liquor from desizing contains a high concentration of BOD. Also present are chemicals, sodium chloride and caustic soda, added to the process bath. The pH of the liquor will be approximately neutral. The most important criteria used in determining the waste loads is BOD.

The BOD load requires treatment since it is the organic material that contributes most to stream pollution. Little can be done to reduce the BOD loading as long as sizing of warp yarns is continued. Because this is so, a substitute is needed or treatment provided. Some improvement has been made by the introduction of low BOD sizing compounds.

**Scouring.** Cotton is scoured to remove natural and acquired impurities. Most cotton is mechanically picked and contains dirt, oil, and trash acquired when it is picked. Cotton also has natural impurities such as waxes, pectins, and oils, which must be removed.

Scouring is accomplished by the use of caustic soda (1 to 8
percent on weight of the fiber), soda ash (1 to 3 percent OWF), pine oil, and usually sodium silicate. These chemicals will all be present in the effluent from scouring and rinsing.

Fabric has been scoured in kiers, open and pressure type. The process is usually carried out at the boil, causing the effluent to be hot. Continuous scouring, using J-boxes, is replacing the batch kier. This process requires less space, steam, water and chemicals than the kier process. It also is much faster and requires less labor.

Waste liquors from kier scouring contain high concentrations of alkalinity and BOD as well as solids. Rinse waters following scouring also contain these impurities, but are less concentrated. Continuous scouring produces the same impurities, but the concentrations vary because the impurities are removed by the rinsing operation.

**Bleaching.** Bleaching is performed on fibers to produce a white product, either for sale as an end product or one to be dyed a light shade. Cotton contains organic matter that gives it a "dingy" color. The color can be removed by an oxidizing agent. The most commonly used bleaching agent is hydrogen peroxide, but sodium hypochlorite, chlorine dioxide, sodium perborate, and others have been used.

Like scouring, the process is carried out either batch wise or continuously. The impurities and chemicals are removed from either process in the rinses. The impurities from peroxide bleaching are; BOD, peroxide, alkalis, and solids. The high BOD from the process is believed to be contributed by the process chemicals used and not much is contributed by the fabric.

**Mercerizing.** This process is used to improve the luster, strength,
and dye affinity of cotton. Mercerizing is accomplished by saturating the fabric with concentrated caustic soda (15 to 25 percent OWF). The caustic soda reacts with cotton very rapidly (1/2 to 3 minutes) and then must be removed by washing. Rinsing following mercerization contributes some BOD, but the most significant contribution is the alkalinity from the caustic.

Most of the caustic is removed from the fabric in the first and second wash baths following the tenter frame. Further discussion on the removal of caustic is given in Chapter VI.

Dyeing. Dyeing is a very complex science used to produce a wide range of colored textile products. Many classes of dyes based on the method of application (azoic, developed, direct, reactive, sulfur, and vat) are applied to textile goods. Each of these classes of dyes are applied using different auxiliary chemicals.

Dyeing is usually followed by rinsing which removes the process-chemicals from the fiber. The auxiliary chemicals are not combined with the fiber and they are the largest polluting component. A very significant example is the high concentration of sodium chloride (salt) that is used with direct dyes. The BOD from dyeing is generally very low compared to any other finishing process.

Most dyes are not completely exhausted during dyeing; therefore, some color is present in the effluent. The dye color in waste water is pollution which people observe and it is objectionable.

Many new developments have taken place in dyeing in the last few years. New dyes and auxiliary chemicals are now being used. New processes are now employed to dye fibers.
Dyes are similar to synthetic drugs and may have a similar and sometimes adverse effect on man. A research project sponsored jointly by the A. French Textile School and the Water Resources Center, Georgia Institute of Technology is underway to determine and evaluate the composition, character, and severity of color pollution; and to devise methods for color abatement.

Printing. Printing is a very useful method of obtaining colored patterns and designs on fabric. Two processes are employed for printing on textile products. They are roller printing and screen printing.

Roller printing consists of passing the fabric around a large cylinder between smaller rolls around the periphery. These smaller rolls are engraved with the pattern to be printed on the fabric. The print paste carrying the color is applied to the engraved rolls and then to the fabric as it passes under these engraved rolls.

The fabric is taken through the roller press by a "back-gray" cloth which is continuous. The back-gray passes through a washer to remove absorbed excess printing paste as it continuously moves around the press.

The fabric leaves the press and passes through driers. The fabric depending on the type color matter applied, may be steamed, aged, or acid treated to fix the color. The only waste produced in printing comes from the washing of the back-gray and from spills.

A second pollutional source is the "color shop" that prepares the printing pastes. Spills and excess paste that reach waste water carry a very high BOD and chemical concentration.

Screen printing is similar to roller printing in basic principle, but the mechanical operation is much different. The process is performed
by rubbing the paste across the screen which has holes in it that represents the design or pattern. The paste passes through the holes in the screens on to the cloth and leaves the design on the fabric which lies below the screens. A back-gray of a different type is used on this operation. It must also be washed. The same pollutional sources exist with screen printing as for roller printing, but the degree of pollution is less with screen printing.

**Finishing.** To produce the required appearance and handle, and to impart desired physical character to fabric, it is usually "finished" as the last step in wet processing. Many different types of finishes are applied to fabrics. Some of these are stain-resistant, water-resistant, fire-resistant, softening, and permanent press.

Finishing usually consists of padding on the finishing chemicals and curring the finishes. The finishing chemicals are incorporated in the product and the only waste consists of spills and dumping of excess chemicals.

**Additional.** Soaps and detergents are used in many of the wet processes and in washing and rinsing. Soap and detergents generally contribute a high BOD to the waste water effluent.

**Wool Wet Processing**

As wool comes from the sheep it contains many impurities either produced by the sheep or picked up from the habitat of the sheep. Raw wool directly from the sheep is commonly called "grease wool". From 40 to 60 percent of the weight of the grease wool may be impurities. These impurities are removed from the wool by scouring.

To the author's knowledge no grease wool is scoured in Georgia.
All Georgia mills processing wool start with scoured wool, and then either make yarn or fabric. The type of mill that finishes scoured wool will be discussed since several operate in Georgia.

The finishing processes for wool are scouring, dyeing, oiling, fulling, carbonizing, and washing.

Scouring. As stated wool has had the natural impurities removed before it is processed, but following weaving wool may be given a light scour to remove any impurities picked up in processing. Synthetic detergents may be used. Little waste is produced by this process.

Oiling. For protection of the fibers, an oil is applied to them prior to dry processing. These oils must be removed in wet processing. These oils have a high BOD.

Fulling. This process shrinks the loosely woven wool from the loom into tight, closely woven fabric. Fulling is effective because of the felting quality of wool.

For fulling, soap, soda ash, and a sequestering agent are padded on the fabric which is then fed into a fulling mill. The fulling mill gives the wool mechanical action to cause the fibers to interlock by means of the scale-like plates covering the outside of each fiber.

Fulling does contribute a high BOD from the soap solution used in the fabric. The carding oil previously mentioned is washed out by fulling. These wastes are removed by the washing following fulling.

Carbonizing. This process destroys vegetable matter adhering to the wool. Sulfuric acid is used to char the matter, although aluminum chloride or magnesium chloride are occasionally used (42).

Mechanical action is applied to the fabric to crush and shake the
foreign matter from the fabric once it has been treated with the acid. Following the mechanical action the fabric is washed. Washing is used to remove the acid from the fabric so it can be further processed.

Very little BOD results from this process. The chemicals added are removed and discharged to the effluent.

**Dyeing.** As with cotton, wool can be dyed in three physical forms—fiber, yarn, or fabric. The processes are similar to cotton dyeing except that different classes of dyes are used and the solution is usually acid. All auxiliary chemicals and unexhausted dye are discharged to the wastewater effluent.

**Man-made Fiber Wet Processing**

Man-made fibers are frequently blended with natural fibers to produce products that combine the desirable qualities of both classes of fibers. The resulting blend is either processed on the cotton system or the wool system, depending on which fiber it has been blended with.

Man-made fibers do not contain impurities such as raw cotton and wool do, since their manufacture is carefully controlled.

When they are processed alone the only contribution to waste water is from the chemicals used in processing. With the new processes such as the thermosol range, little waste is produced.

**Treatment Requirements**

**Classical Survey**

A standard method for a sanitary survey to estimate the pollution load of a textile mill consists of sampling, analyzing, and measuring flow of every rinse and process bath discharged to waste.
Another approach would be to take continuous samples of the composite effluent from the mill. Here, as with the first method accurate sampling must be performed. Of course, the first method has far greater definitive accuracy than sampling the composite.

The results of sampling each discharge must be proportioned to the total flow rate of the mill. Calculations can be made from the data obtained by the sampling of each source to give a rather accurate measurement of the pollution load of the mill.

Considerable work and experience are required to make these surveys and they may take several months for completion. Complications exist if the mill finishes a variety of products.

Because of the effort required and the accuracy of standard surveys, a much easier method has been developed which gives as good results as the standard surveys. The new method, called Simplified Pollution Survey, has been suggested and experimentally developed by Wesleyan University (43).

Simplified Pollution Survey

This method is based on the pounds of goods that are processed and the pounds of chemicals used. The impurities removed from the fiber, yarn, or fabric can readily be determined from laboratory analysis. The pounds of goods processed through each different operation can be obtained from production records. The quantities of process chemicals used can be determined from the plant inventory system or the individual process formulas. Water consumption data is generally readily available if the mill buys water from a supplier. If the mill has its own water supply, water consumption can be obtainable from the records of the water plant.
By knowing the pounds of goods processed, a routine laboratory analysis of samples of all goods can provide figures on the amounts of impurities removed in each process. It is necessary to obtain a sample of each different type product processed. Only little additional time and effort are required to accomplish this sampling. The laboratory is required to run BOD tests on baths of these samples. Still the number of tests are greatly reduced.

BOD figures are available for many of the process chemicals used. A list of the BOD of textile chemicals updated to 1966 appears in the American Dyestuff Reporter (44). If the BOD value is not known, a BOD determination must be performed by the laboratory.

With this information a knowledge of the mill effluent can be constructed by direct calculations. The factors required are:

1. pounds of goods passed through each process,
2. water consumption,
3. pounds of chemicals used in each process,
4. pounds of impurities (BOD) removed from each type of goods processed, and
5. the BOD of chemicals used.

Those processes that are known to produce very little waste can be eliminated from this type survey. Only the volume of water used for them must be considered.

Once the five items have been determined and the necessary calculations are made, the method of treatment and the treatment capacity can be devised.

Individual mills will obtain specific and different results from their surveys. The literature contains several summary tables of impurities contained in typical mill effluents. An example is given in Table Four (45).
Treatment Methods

A great deal of work has been done in the field of textile wastewater treatment. The bibliography of Jones and Hyden cites 490 references (46).

Waste treatment is the final action for pollution reduction. Methods of reducing the pollution load are outlined in Chapter VI of this thesis. Once the necessity of treatment has been established and a quantitative waste survey has been made, the kind of treatment to be used can be determined.

Table 4. Summary Results of Mill Surveys

<table>
<thead>
<tr>
<th>Process</th>
<th>pH</th>
<th>Alkalinity</th>
<th>BOD</th>
<th>Solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desizing</td>
<td>6.8</td>
<td>146</td>
<td>3889</td>
<td>6680</td>
</tr>
<tr>
<td>Scouring</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st Boil Kier</td>
<td>12.2</td>
<td>24972</td>
<td>9643</td>
<td>48754</td>
</tr>
<tr>
<td>2nd Boil Kier</td>
<td>12.0</td>
<td>14825</td>
<td>1865</td>
<td>11915</td>
</tr>
<tr>
<td>1st Rinse J-box</td>
<td>11.6</td>
<td>974</td>
<td>530</td>
<td>2201</td>
</tr>
<tr>
<td>2nd Rinse J-box</td>
<td>10.5</td>
<td>89</td>
<td>35</td>
<td>231</td>
</tr>
<tr>
<td>Bleaching</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypochlorite</td>
<td>7.7</td>
<td>47</td>
<td>61</td>
<td>263</td>
</tr>
<tr>
<td>Peroxide</td>
<td>8.9</td>
<td>109</td>
<td>58</td>
<td>305</td>
</tr>
<tr>
<td>Mercerizing</td>
<td>12.3</td>
<td>3515</td>
<td>23</td>
<td>3296</td>
</tr>
</tbody>
</table>

The treatment facilities must be so designed that they perform the function for which they were intended. They must be flexible to provide for future changes in plant processes. This flexibility should extend, so far as possible, to incorporate new techniques or means of treatment developed in the future. The design should also include ways and means of
providing treatment should mechanical failure or natural disaster cause some part of the treatment plant to become ineffective. Of course a bypass should be included to be used if an emergency arises.

Treatment of waste water has one objective—to remove that matter in the effluent that will render the receiving stream unfit for necessary and undesirable purposes. The most important factor concerning treatment in an effluent is the BOD load. The BOD load, i.e., organic matter, tends to consume the oxygen in the receiving stream. The oxygen is utilized by organisms in nature to consume the organic matter in the stream. As textile wastes are discharged, if the organic load is such that the oxygen is consumed faster than it is adsorbed by the receiving stream, then a condition of pollution exists. Depletion of a stream's oxygen causes polluted conditions— as evidenced by fish kills and odor.

Of course the addition of non BOD substances will also cause polluted conditions. Examples are chemicals such as caustic soda, sodium chloride, and dyes. These chemicals may cause a condition that does not permit biological life to exist in the receiving stream. As troublesome as these are, BOD is still the most important item.

A waste-water treatment plant is a facility which increases the rate of destruction of the organic waste matter by the natural organisms. In principle, the plant accelerates the process that takes place naturally in a receiving stream. The treatment is accomplished by supplying the oxygen necessary for the organisms to utilize the waste. The reaction for a simple organic compound that represents the utilization of organic wastes in the presence of oxygen is:

\[ C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O \]
When the reaction takes place in the presence of oxygen it is called aerobic oxidation.

If no free oxygen is present another form of organism will utilize the organic matter by anaerobic digestion. These organisms are capable of using the energy which is combined in the organic matter. The reaction is:

$$C_{6}H_{12}O_{6} \rightarrow 3CH_{4} + 3CO_{2}$$

The energy containing compounds are then released to the atmosphere or they are burned.

With the exception of controlled anaerobic digestion units, aerobic digestion is preferred since the products of aerobic digestion are in a higher oxidation state than the anaerobic products. Anaerobic products may have an undesirable odor ($H_{2}S$), when sulfates or inorganic sulfides are present.

Waste-water treatment has been classified as primary and secondary. In recent years more advanced treatment has been introduced and called tertiary. Georgia laws require that waste-water be given at least secondary treatment.

Primary treatment consists of screening and sedimentation to remove floating and suspended solids. The degree of treatment usually runs about 40 percent BOD removal.

Secondary treatment consists of primary treatment followed by biological or chemical treatment. Biological treatment systems may be activated sludge tanks, trickling filters, lagoons, or spray irrigation. Chemical treatment, as in water purification, consists of coagulation,
precipitation, and sedimentation. Secondary treatment removes from 80 to 95 percent of the BOD load.

Tertiary treatment would be additional treatment given waste water following secondary treatment. This advance treatment could be some chemical or biological process to provide a higher percent BOD removal. Some of the more advanced forms of treatment are activated carbon adsorption, electrodialysis, evaporation, foaming, freezing, and solvent extraction.

Municipal Disposal of Textile Wastes

A desirable method in some cases of disposing of textile waste water is to combine it with municipal sewage. The desirability of this course of action depends on the availability of a municipal system into which the waste water may be discharged. Small mills which can dispose of their waste water to a municipal system have a very desirable situation, because the cost of providing treatment facilities may be large. The lack of space upon which to construct a treatment plant may give the mill no alternative but to place their discharge in a municipal system.

Treatment of combined textile mill waste and domestic waste has been very successful (47, 48, 49). The high pH and alkalinity can be treated on trickling filters, but if a high degree of treatment at heavy loadings is required then caustic will have to be neutralized. Prolonged treatment in aeration tank is another possible treatment method for highly alkaline wastes.

Most municipalities use some form of biological treatment for their waste water. Textile waste may be of a nature that they will have an deleterious effect on biological treatment. In such a case some form
of preparatory treatment is required. Cooperation between municipalities and mills have often provided acceptable solutions to combined treatment with advantages to both the mill and the city.

Preparatory Treatment

Preparatory treatment of textile wastes may be mandatory either to conform to municipality treatment or to assist in mill treatment. Shockloads (intermittant discharge of large volumes of waste) may be objectionable because of temporary overloading of the treatment plant. Holding or storage basins are needed to regulate such discharges.

Neutralization with either sulfuric acid or carbon dioxide may precede treatment of wastes by activated sludge tanks or trickling filters. The above mentioned holding basins will provide facilities for combining alkaline waste, bleaching wastes, acid wastes, and dye wastes. The effect of this combination may provide a composite waste of a lower pH and colored to a less degree than intermittent discharge. Similarly separation of specific wastes may provide opportunity for better treatment than combinations. Collection of wash water from the mercerizing process which are sufficiently concentrated to justify recovery of the caustic soda is such an example. Caustic recovery is presented in Chapter VI.

Controlled addition of sulfuric acid to high pH wastes can be accomplished by a monitoring system. Even though sulfuric acid is relatively inexpensive, the cost of neutralizing large volumes of waste water may become very high. Another method of lowering pH is by adding carbon dioxide by piping flue gas into the waste water (50). This latter method requires complex piping and control equipment that may not make it economically attractive.
Chemical Precipitation

Chemical coagulation has been used successfully for textile wastes. The process is operated like that used for process water purification. The most common used coagulants are alum and lime. Ferrous and ferric compounds are used to control pH. Chemical addition, rapid mix, sedimentation, and sludge removal are required to remove the impurities. The process is ineffective in removing soluble BOD.

This method of treatment is costly in equipment and chemicals used. Better methods of treatment such as biological treatment are available and should be used. However, this method may have very desirable application in specific cases if used in conjunction with other forms of treatment.

Activated Sludge Process

The process consists of mixing waste water with previously treated sludge. The mixing is done in the aeration tank. Following the aeration tank the suspended matter is allowed to settle and a clear liquor is discharged. The activated sludge from the secondary settling tank is the source of the sludge to be returned to the aeration tank. Figure (15) represents a lay out for an activated sludge plant.

All wastes water treatment plants should employ some form of screen as the initial treatment device. The screen may be a simple row of bars located in the path of the waste flow. It is necessary to remove any solids of large mass that might interfere with the following treatment.

From the screen the waste moves to the primary settling tank. Where the reduced velocity of flow allows the suspended solids to settle. The settled solids (sludge), which has not received any treatment, are
Figure 15. Activated Sludge Plant
usually pumped to digestion tanks. This operation concludes the "primary treatment". The same operations are used for all forms of biological treatment which require primary treatment. Several methods exist for the disposal of the sludge produced by primary treatment, but digestion tanks are usually the most desirable.

The activated sludge tank (aeration tank) is the principal component of the secondary treatment system. The tank must be large enough to provide sufficient detention time (3 to 8 hours) to stabilize the waste. Air is pumped into the tank to provide oxygen and mixing. Sludge from the secondary settling tank is returned to the aeration tank. The activated sludge contains the organisms which utilize the fresh wastes and also provides the medium for biological growth. The effluent from the primary settling tank flows into the aeration tank.

Following the aeration tank is a secondary settling tank. This tank is the source of the activated sludge to be returned to the aeration tank. As more and more waste is treated excess sludge is produced. This sludge is removed and treated in the digestion tanks. The supernatant liquor can be discharged to a receiving stream.

The digestion tank is enclosed since anaerobic digestion takes place here and gases are produced. Digested sludge is removed from the digester and dried on sludge beds. It may be used as fertilizer.

The activated sludge process provides a high degree of treatment. Large quantities of organic waste can be treated in a smaller area than in any other treatment process. The process is sensitive and control of the process is very critical. It requires a skilled operator to run the plant. Shock loads may seriously upset the operation and prevent adequate
treatment. Pumps are required to provide oxygen to the aeration tank and sludge return pumps cause operation costs to be high.

A recent modification of this process is called extended aeration. This process consists only of an aeration tank and a settling tank. Again a screen should precede the treatment.

The aeration tank has some form of aeration either pumped air or mechanical surface aeration. The operation is similar to activated sludge. Following the aeration tank is a settling tank. Sludge from the settling tank is returned to the aeration tank. No provisions are made for sludge disposal. The detention time is much greater than for activated sludge. The objective is to have all the wastes consumed in the aeration tank.

Surplus sludge will be produced and means for disposal must be provided. If it is allowed to build up in the settling tank, the reduced volume of the tank will not provide proper settling and sludge will be discharged into the receiving water. The excess sludge can be drawn off the settling tank and discharged to the receiving stream.

The degree of acceptance of the method of treatment for large volumes of wastes is questionable but this type treatment has the possibility of meeting the needs of small volumes of wastes. Operation is simple and construction costs are relatively low.

One Georgia mill has installed this type of a system and reports effective results (51). The mill is to be commended for installing the treatment several years before legal requirements for treatment had been established. They are also to be commended for undertaking the application of a new method of treatment to textile wastes.
Trickling Filters

This process uses similar type screens and settling basins to those used in the activated sludge process. The secondary treatment is provided by trickling filters. The filter is a large circular tank filled with some filter medium. In the past large natural stones were used exclusively. Today, synthetic materials are available which have been successfully used as filter bed medium.

Figure 16 is a diagram of a trickling filter plant. Figure 17 is a diagram of a trickling filter.

The effluent from primary settling is dosed on the trickling filters. The dosing is accomplished by the water flowing through a rotating arm which distributes the water over the entire surface of the bed. The bed is so constructed that air fills the voids in the bed. The water trickles down through the bed. A slime growth adheres to the stones in the bed and microorganisms in the slime consume the organic waste. When the slime growth builds up sufficiently it drops off the stones and passes to the secondary settling tanks.

Trickling filters are very effective in treating waste water. They provide a high percentage of BOD removal. Filters are capable of withstanding shock loads. The medium in filters is stationary, unlike the activated sludge medium in aeration tanks. In the event a toxic material enters the treatment plant and destroys the organisms, trickling filters can be replaced in service easier and more quickly than activated sludge tanks. Trickling filters are capable of operating under wider ranges of pH than the activated sludge process.

Trickling filters require more area and are expensive to build. They are easy to operate and do not require a highly skilled operator.
Figure 16. Trickling Filter Plant

A. Influent
B. Bar Screen
C. Primary Settling
D. Trickling Filters
E. Secondary Settling
F. Effluent
G. Sludge Drawoff
Figure 17. Trickling Filter

A. Influent
B. Stone Bed
C. Underdrain
D. Effluent Discharge
E. Rotating Distributer
The operating cost are less than for activated sludge treatment because flow is usually by gravity and no pumping of air is required.

Lagoons

The fourth method of treating waste water is lagooning. Two types of lagoons are employed. An anaerobic lagoon system has been under study, but its application has not yet been completely developed. Imhoff tanks and septic tanks are a form of anaerobic lagoon that has been used for many years. They could feasibly be used to treat textile waste water.

The aerobic lagoon has become an accepted method of secondary treatment. This type of lagoon has become known as an oxidation pond, but is also known as a waste stabilization pond.

The oxidation pond is relatively inexpensive to construct. Land is usually the largest cost. The recommended loading is 35 pounds of five day BOD per acre per day. Loading of up to 50 pounds of five day BOD per acre per day may be acceptable. At these loadings large mills may have to construct ponds of large acreage.

They are effective as treatment processes for textile waste water. Little maintenance is required and no operator is required, but the pond should be under some supervision.

Construction and operation are outlined in two publications of the Georgia Water Quality Control Board (52, 53). The design is simple. The ponds are built with a depth of five feet with an operating level of 3.5 feet. Waste water enters the pond under the surface about 1/3 the length of the pond centered from each side. Usually the ponds are rectangular in shape. Of course the design can be changed to meet the available land. The discharge is located at the shore of the pond away from the influent.
The pond is a combination of all the treatment processes which take place in separate units of conventional treatment plants. The pond provides primary treatment through its large area which allows settling of suspended solids. Aerobic digestion, secondary treatment, proceeds in the upper portion of a pond. The organisms oxidize the organic wastes load. The waste that settle to the bottom are decomposed by anaerobic digestion.

A pond must have a bottom that liquid loss due to seepage and percolation cannot take place. If water is allowed to pass through the porous bottom pollution of ground waters may result.

Algae thrive in oxidation ponds. They are important in generating oxygen for treatment in the upper portion of the pond. Algae also create a problem. They may cover the surface and prevent sunlight from entering the pond and lack of sun light will slow the operation of the pond. The algae also create a nuisance in receiving streams if they are discharged. Proper operation such as discussed in the Division for Georgia Water Quality Control's technical bulletin can keep algae nuisance to a minimum.

The loading capacity of oxidation ponds can be greatly increased by the addition of surface aeration to the ponds. Mechanical aerators have been used to assist in treatment in oxidation ponds. When land is not available to provide sufficient area for treatment, mechanical aerators can be used to provide proper treatment by using a much smaller pond.

**Sludge Disposal**

Several forms of treatment require sludge disposal. The most widely used method of sludge treatment is by use of anaerobic digestion tanks. A diagram of a digestion tank is in Figure 18.

Other methods of disposal are sludge drying beds, vacuum filters,
Figure 18. Sludge Digestion Tank
Other methods of disposal are sludge drying beds, vacuum filters, flash driers, and incinerators. Raw sludge cannot be exposed to drying beds where odors would be a problem.

**Choice of Treatment**

The choice of treatment for textile waste depends on many factors. Decisions can only be made after a survey of the pollution load and its character is completed. The degree of treatment required and the availability of capital, land area, and skilled labor will help to determine the type of treatment to adopt. It is axiomatic that once the choice is made, a well designed plant should be constructed and properly operated.
CHAPTER VI

IN-PLANT MODIFICATIONS TO IMPROVE WATER UTILIZATION AND WASTE-WATER DISPOSAL

General

Many of the large water using industries such as petroleum refining, steel milling, and chemical manufacturing have developed large scale programs for water conservation through reuse (54). However, in-plant modifications to reuse or to consume water seem to have been somewhat neglected in the textile wet processing industry. Some proposals have been cited in the literature for textile waste-water control.

The author participated in a survey of the Georgia textile industry and some of the more significant findings are discussed in the following (55).

Some in-plant modifications which the textile industry might make to good advantage are: improved housekeeping, improved process control, process chemical substitution, recovery of process chemicals and baths, process byproduct recovery, segregation of concentrated and weak waste water, water reuse, heat recovery, and machinery modifications.

Improved Housekeeping

Housekeeping practices are closely allied to safety. Housekeeping is a minor factor in reducing pollution loads. Better housekeeping can reduce the number of rejects and reprocessing of finished goods. Less dirt, grease, and rust, on the fabric means that less washing is needed
to remove impurities.

By having drains so constructed that dirt from floors cannot enter the waste water discharge, contamination can be reduced. One mill has used small concrete ridges about eight inches square to encircle wet processing operations. These ridges prevent water from spreading from the operations and prevents outside impurities from entering the drains.

Good housekeeping provides an attractive surrounding for employees to work. The merit of this is self-explanatory.

**Improved Process Control**

Closer process control can reduce pollution loads. By precisely adjusting the chemical requirements to match the needs of finishing the goods, minimum quantities of chemicals will be used. Similarly, strict improved process control leads to water conservation. The prevention of leaks and control of excess flow helps conserve water.

Computer manufacturers are working on the development of systems to be used for textile wet processing. By programming the operations on the basis of the goods to be finished, chemicals to be used, and water requirements, better process economy can be obtained. At this time one manufacturer has such a program under development. Because it is in the development stage, little information is available.

Hopefully, computers will improve water management and waste-water disposal.

**Chemical Substitution**

Pollution reduction by process chemical substitution can be achieved in some cases. One outstanding example is the substitution of CMC
(carboxymethylcellulose) for starch as a size compound. Because about 50 percent of the BOD load of a cotton finishing mill comes from desizing, a reduction of at least 40 percent in total BOD can be realized by such a substitution (56).

The use of lower BOD chemicals in any and all processes would have a marked effect on the effluent character. Some possibilities are: low BOD synthetic detergents for soap, steam range oxidation for chemical oxidation, and sulfuric acid for fulling soap.

**Chemical Recovery**

The recovery of process chemicals is not new to industry. The pulp and paper industry in Georgia has been recovering process liquors for years. Some elements of the textile industry have been recovering caustic soda for more than a decade. Process chemical recovery not only results in operating economy, but produces a beneficial effect in pollution control as well.

The most significant and proven chemical recovery is that of caustic soda from the mercerization process. One Georgia textile mill has successfully recovered caustic from mercerization for 12 years. Other large mercerizing mills have plans to install equipment to recover caustic soda.

Caustic soda discharged into streams or treatment plants has an adverse effect on biological activity. While the caustic can be neutralized the cost may be prohibitive, as explained earlier. Furthermore, neutralization does not reduce the quantities of the undesirable sodium ion. Recovery of caustic soda will reduce the volume discharged and perhaps neutralization will not be needed.
Two research projects of the A. French Textile School have shown that recovery is feasible (57, 58). Mr. Jones’ thesis gives a review of the literature of caustic recovery and outlines methods of recovery. The thesis of Mr. Becknell demonstrates the reuse of recovered caustic without evaporation or other expensive treatment.

The economy of evaporation and dialysis to recover caustic soda from mercerization are given in an article by Nemerow and Steele (59). The reduction in cost of waste water treatment can also add to the desirability of caustic recovery.

Recovery of other process chemicals seems feasible. Practice of chemical recovery other than caustic is not widely practiced in the textile industry. This field will be explored and be developed if the processes improve the economical operation of the mill. One area now under-study is reuse of dye baths. If feasible this will reduce the volume of auxiliary chemicals required; and will result in a savings. If only a slight reduction in pollution is gained from this and other chemical recoveries, it will be a considerable contribution.

Byproduct Recovery

Recovery of wool grease, in particular lanolin, has been practiced for years. Possible recovery of byproducts from cotton finishing is a distinct possibility. Some investigation of cotton byproducts has been made (60). The efforts of this work have not yet borne fruit.

Some promising areas for byproduct recovery are natural impurities and desize wastes. These wastes contain glucose which could possibly be used as a food supplement.

One suggested method is evaporation of the concentrated waste. In
this operation another byproduct, steam, could be used in the mill. The controlling factors in byproduct recovery are the cost of recovery, the marketability of the byproduct, and the cost of alternate methods of disposing of the byproduct (waste water treatment).

Segregation of Wastes

By segregating concentrated waste water from weak waste water the volume of water to be treated may be reduced. Rinse water that does not contain a heavy BOD load or other polluting component could be discharged without treatment. The value of segregation of waste waters for treatment purposes depends on the types and quantities of impurities in the water. Some wastes are easier to treat separate rather than when combined with other waste water.

Water Reuse

Reuse of water is being investigated by some textile mills. It is rather common practice for the water used by one mill to be discharged to a receiving stream, and later, downstream, used again by another mill. At present Georgia has ample water to meet all projected needs through the year 2000. Even so, reuse of water has advantages for Georgia mills. Water reuse can be classified in two separate classes, that is, without treatment and with treatment. The advantages of reusing water without treatment are decreased process water costs and decreased volume of waste water.

Many baths and rinses are not contaminated to the point that they cannot easily be reused. One mill reused its after dyeing rinses to prepare fresh dye baths. Rinses following finishing could be reused to
rinse following scouring.

With the water shortage occurring in some sections of our nation, the reuse of water is becoming more and more important.

A system using gas turbines as an energy course to generate electric power could be used to reclaim water. Exhaust heat from the turbines could be used to evaporate effluent water. The water vapor then would be condensed and used as hot process water. The method also eliminates the need of boilers to heat process water.

Several methods of water reclamation have been developed (61). These systems include chemical precipitation, sedimentation, filtration, ion exchange, activated carbon treatment, and demineralizers. Each system must be tailored to the quality of the effluent water and the quality of the required process water.

Reuse of polluted process water can be accomplished by reclaiming the used water. Surface supply water has to be treated before it can be used. Now waste water must be treated before it is discharged. If the two treatments are combined to produce process water from effluent water, the resulting treatment may be less costly than the separate treatments.

Some water could be reused after screening to remove solids. This screening is particularly important in caustic recovery to remove lint. Lint removal is also important for waste water disposal to treatment plants. A mechanical screen system has been developed that is most effective in removing small solids from water (62). These mechanical screens can be used to separate solids from water.
Heat Recovery

Much of the effluent water from textile mills is hot. The heat energy discharged with the hot water is an economic loss. If the heat can be recovered economically, it would be an asset to efficient mill operation. Heat is usually undesirable in the effluent because oxygen is less soluble in water at higher temperatures, and fish thrive better in cooler waters. By recovering heat from process water, pollution abatement is facilitated.

Heat can be recovered by the use of heat exchangers (63, 64). The exchanger is a shell and tube unit. Hot waste water passes through the tubes and fresh water flows in the shell surrounding the tubes. The fresh water flows countercurrent to the waste water which provides maximum efficiency.

Machinery Modifications

Modification of machinery can result in more efficient use of water with a reduction in quantities discharged to sewers and streams. An example is the new closed beck for carpet dyeing (65). Such developments should be encouraged.
CHAPTER VII

CONCLUSIONS

1. Water is the most important chemical used in wet processing textile operations.

2. Good management of water supply, water quality, water conservation, waste disposal via water transport, and re-use of water is imperative for the textile industry in Georgia and in the nation. It will become increasingly important in the future as industry expands, population grows, and demands for water become greater.

3. Good management of water use, waste disposal, and pollution abatement requires basic knowledge of technical, sociological, legal and political factors which bear upon these matters. To provide information and guidance for this requirement this dissertation summarizes current and salient facts in the areas of:

   a. legal stipulations,
   b. water supply,
   c. water purification,
   d. waste-water treatment, and
   e. in-plant modification

and cites literature references regarding each of these.
CHAPTER VIII

RECOMMENDATIONS

It is hoped that this thesis may serve as a guide and a check list for textile mill managements when dealing with water problems, by out-lining and summarizing procedures which may be followed. It is recognized, however, that only concepts and generalities can be given in a work of this scope. Furthermore, new information is constantly coming forth from research and experience. For these reasons the reader and user is asked to consult with the Water Resources Center, Professor Carl Kindsvater Director, at the Georgia Institute of Technology for detailed and latest information before embarking upon specific projects.

Other agencies which the user should also contact are:

Georgia Water Control Board
Georgia Textile Manufacturers Association
Industrial Development Division Georgia Tech
Federal Water Pollution Control Administration
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