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AN INDUSTRIAL WASTEWATER TREATMENT REVIEW FOR THE
TEXTILE AND PULP AND PAPER INDUSTRIES
OF SRILANKA

BY

KOLONNE A. WIJERATNE
B.Sc., University of Srilanka, 1967

RESEARCH REPORT

Submitted in partial fulfillment of the requirements
for the degree of Master of Science
in the Graduate Studies Program of
the College of Engineering of
Florida Technological University

Orlando, Florida
1976

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ABSTRACT

A legislative authority empowered to protect Srilanka's environment, operating similarly to the Environmental Protection Agency of the U.S., is needed, along with wastewater treatment. Wastewater parameters of importance in treatment are BOD, COD, total suspended solids, settleable solids, pH, colour, turbidity, ammonia or nitrate nitrogen, heavy metals, sulfides, phosphates, and phenols. Methods of industrial waste treatment vary depending on the climatic conditions, the industry, raw materials, and process adopted.

Textile and pulp and paper industries exist in Srilanka and have very high pollution potential. Methods of treatment to finally generate reasonably good quality effluent are available. Processing of effluents from these type industries together with municipal sewage is feasible and economical.

Due to the complex nature of the composition of industrial wastes, a final decision could only be made after a thorough investigation of the industrial complexes, the methodology used, and pilot plant studies.

Waldron M M Tellez, PE
Director of Research Report

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	iii
ABSTRACT	iv
Chapter	
I. INTRODUCTION	1
II. SRILANKA INDUSTRY AND WATER RESOURCES	5
III. POLLUTION PARAMETERS	24
IV. THEORIES AND METHODS OF INDUSTRIAL WASTEWATER TREATMENT	33
V. TEXTILE INDUSTRY WASTES AND WASTEWATER TREATMENT . . .	41
VI. PULP AND PAPER INDUSTRY - WASTES AND WASTEWATER TREATMENT	77
VII. CONCLUSIONS	113
LIST OF REFERENCES	116

LIST OF TABLES

2-1	Names of Rivers and Waterways Shown on Figure 2-3	12
2-2	Industries and Locations for Figure 2-4	14
4-1	Removal Efficiencies of Sedimentation and Biological Methods in the Removal of Metal Traces in Sewage Treatment	38
4-2	Adsorption by Activated Carbon	39
4-3	Carbon Adsorption of Mn, Cu, Ni, Cr, Hg, and Pb . . .	40
5-1	BOD of Commonly Used Sizing Compounds and Quantity Used Per 1,000 lbs. of Fiber	44
5-2	Chemicals Present in Cotton Dye Baths	47
5-3	Pollution Effect of Cotton Processing Wastes	49
5-4	Characteristics of Cotton Processing Wet Wastes . . .	50
5-5	Pollutional Load of Synthetic Wet Fiber Processes . .	54
5-6	BOD Loadings of Polyester Dye Carriers	60
5-7	Removal Efficiencies of Treatment Methods Used, Synthetic Fiber Wet Processing Wastes	66
5-8	Peak Colour Removal Efficiencies of Treatment Methods Used	68
6-1	Raw Waste Characteristics of Pulp and Paper Industry, Per Ton of Product	88
6-2	Composition of Typical Sodium Based NSSC (Sulfite) Wastes	89
6-3	Characteristics of Kraft Mill Wastes	91
6-4	Waste Loads and Wastewater Characteristics of Different Paper Production Processes	93

6-5	Primary Treatment Data - NSSC Waste Monthly Averages	103
6-6	Biofiltration	104

LIST OF FIGURES

2-1	Srilanka's Wet and Dry Zones	8
2-2	Srilanka's Rainfall	9
2-3	Srilanka's Rivers and Waterways	11
2-4	Location of Srilanka's Industries	12
5-1	Process Flow Sheet for Cotton Goods	42
5-2	Typical Processing of 100 Percent Synthetic Fabric . .	52
5-3	Typical Processing of Blended Fabrics	53
5-4	Cotton Waste Processing Flow Chart	69
5-5	Synthetic Textile Finishing Waste Treatment Flow Chart	70
6-1	Kraft Pulping Process Diagram	79
6-2	Kraft Pulping Chemical Recovery	82
6-3	Neutral Sulfitc Semi-Chemical Pulp Process Diagram . .	83
6-4	Fourdrinier Paper Machine Process Diagram	85
6-5	Waste Paper Board Mill Process Diagram	87
6-6	Land Required for Wastewater Treatment	97
6-7	Process Flow Diagram Mill Effluent Treatment	100
6-8	Colour Removal and CaO, 50% NSSC + 50% Wastewater . . .	106
6-9	Colour Removal and CaO, 100% NSSC Wastes	107
6-10	Colour Removal and Lime + Chlorine, 100% NSSC Wastes .	108
6-11	Colour Removal and Lime + Chlorine, 50% NSSC + 50% Wastewater	109
6-12	Massive Lime Process for Colour Removal	110

CHAPTER I

INTRODUCTION

"A nation that fails to plan intelligently for the development and protection of its precious waters will be condemned to wither, because of its short sightedness. The hard lessons of history are clearly written on the deserted sands and ruins of once proud nations" (1). The above quotation is from a presidential speech of late President of the United States of America, Lyndon B. Johnson. The importance and applicability of this to developing nations should be reviewed by the policymakers and governments in planning the future of their communities.

Environmental pollution control, and pollution prevention, in a developing country with a backward economy, is a difficult task. The world economic inflation has added more oil to an already burning fire of economic problems of underdeveloped and developing countries having little or no oil resources. However, in the struggle to supply the basic requirements and minimum standard of living, various industries producing the essential needs of the society are a must for any nation. Industries mostly consume fresh water resources and generate wastewaters and solid wastes while manufacturing the products. These fresh water resources and wastewater effluents are interlinked by various means. Industrial wastes have created new pollution problems at every corner of the world.

Under modern planning and management of needed industries the place of an environmentalist is highly crucial in developing countries.

Srilanka, although a very small country, has started her own industries in order to cater to the internal consumption of her population. Due to the lack of private funds and various other socio-economic effects, most of the small and major industrial ventures are state owned. However, industries owned by cooperatives or by the private sector are not uncommon. Due to the availability of hydroelectric power the future industrial developments of Srilanka look brighter under a world oil crisis. Also, due to sunny beaches and year round holiday resorts, together with historic places of interest, Srilanka's tourist potential is considered by the World Bank as one of the best in Southeast Asia.

Pollution control is essential in safeguarding the public health, economy, tourist potential, and industry itself of Srilanka.

In considering the various industries of Srilanka today the following could be classified as of major pollution potential: (1) textile industry, (2) tire and rubber goods manufacture, (3) petroleum refining, (4) pulp and paper industry, (5) iron and steel goods manufacture, (6) ceramics manufacturing, (7) tanning and leather goods manufacturing, (8) coconut fibre production and allied industries, (9) coconut oil extraction and allied industries, (10) rice milling. Most of these industrial complexes are only 10-15 years old, and since they are located in the coastal belts 20-30 miles from sea, the direct impact of pollution is not yet felt by most of the population.

However, the pollution potential of one of the old industries, coconut fibre processing in the southern coastal belt, is notable. This already is creating a health hazard due to the fact that the polluted waters are breeding grounds for mosquitoes of a special group carrying Filarisis germs. This pathogen leads to the disease called Elephantiasis, for which no cure has been found in the field of modern medicine, once the disease attains the control of human organs.

The groundwater table in most parts of the island, except for the coastal areas and marshy low lying areas, carries potable water suitable for human consumption.

Environmental protection and pollution control are a dream of the future for an environmentalist in front of ignorant masses, bureaucracy, and lay politicians who are fighting for survival under the inflation existing. In this political climate, the importance of controlling industrial wastes still cannot be neglected. If pollutional effects are allowed to grow without control, they will become giant monsters which can easily eradicate the nation.

Methods of environmental pollution control, the legal framework, and the priority given to environmental aspects in planning the future industries and controlling the available industry in United States of America, act as a strong guideline for less developed and developing nations of the world in planning out their policies and working towards the prosperity of their people.

This report, which considers the Srilanka industries and US and other world experience, is mainly oriented towards a much needed goal of Srilanka to investigate the pollution potential of textile

and pulp and paper industries and the methodologies of treatment.

These are two industries of importance in Srilanka.

CHAPTER II

SRILANKA INDUSTRY AND WATER RESOURCES

Srilanka is an island in Southeast Asia, having a land mass of 25,332 square miles, 270 miles long from south to north at its longest, and 140 miles wide from east to west at its widest. This island is usually described as "pear shaped" with a peninsula at the top like the bent stalk of the fruit. In the thirteenth century, Marco Polo on his way home described Srilanka as "the best island of its size in the world." Portugese named the island "Zelan" with a meaning of a place to be joyful. Srilanka lately became the "Pearl of the Orient" to Europeans (2).

The northern tip of the island is very close to the southern part of India, being separated by a 22 mile wide, narrow strait full of sand banks and low islands. To the south of the island the Indian Ocean stretches till it reaches the Antarctic.

Although Srilanka is a small country by natural formation itself, the history of Srilanka people dates back as far as the 1st or 2nd century, B.C.

Due to the importance of her location in the world of shipping, Srilanka unfortunately became a colonial prize. Portugese came in 1505 A.D. A century and half later, Dutch took over the rule of coastal areas around Colombo from the Portugese. Srilanka's nationalists had to fight against the world's super-power during 1802, after

the Dutch. Finally, in 1818 the British succeeded in ruling the whole island, after capturing the King of Lanka and coming to an agreement to rule the country with due respect to the Sinhalese traditions, laws, and cultural activities. However, the movement to liberate the island never died down. In 1948, Srilanka won political independence under the colonial name Ceylon. After independence the essential need of industrial development inside the island became an essential requirement. These industrial activities took a long time to start and only in 1957 did the basis for an industrial development practically come into operation.

Geologically Srilanka is a slightly detached part of the "Western Ghats" separated by a submerged gap at Polk Straits. The core of the island is a mass of Precambrian crystalline rock which forms the central mountain area, rising up to 8292 feet above mean sea level (A.M.S.L.), known as upland. Encircling these hills and mountains are lowlands, and a coastal plain categorized as lowlands. The upland area could be assessed to be about one fifth of the total land mass, mostly over 1200 feet (A.M.S.L.), rising to peaks and ridges at places. Although the lowland area, consisting of the north and north central part of the island, could be specified to be mostly lower than 300 ft. (A.M.S.L.), at various randomly located places are isolated rocky hills of heights varying from a few hundred feet to peaks of about 2000 ft. Mineral resources of the interior include graphite, gemstones, such as sapphires and rubies, and iron ore.

In the areas around the capital city Colombo, where most of our industry is located, the monthly average temperatures do not vary far outside 78° to 82°F, throughout the year. Winds from the sea are the main controlling factor of Srilanka's rain cycle. Various monsoonal rains falling on the island are named after the direction of the wind with respect to the land mass. Southwest monsoonal rains occur from May to August in the wet zone, which includes most of the upcountry and southwest coastal belt, covering forty miles north of Colombo to a few miles east of "Devundarahead," the southern most tip of the island. Figures 2-1 and 2-2 show the wet and dry zones of the island and the average rainfall pattern of the island. The southeast, north, north central and northwestern areas receive less rain, mainly due to the lack of hills to meet and cool the monsoonal winds. Depending on these natural phenomena, climatic differences exist in different parts of the island, especially between the areas in dry zone and wet zone.

Soft clayey soils with varying mixes of decayed rock, sandy soils, or red colored hard soils known as cabock soils, are common throughout the island, except in the coastal areas where sandy soils are a common occurrence. Due to the seasonal rain, and rich and suitable soils, together with tropical climate, agriculture was the main source of income and the mode of life for the majority of Srilanka's population. Late in the 18th century and 19th century under British colonial rule, Ceylon became a world reknown exporter of tea, rubber, and coconut products.

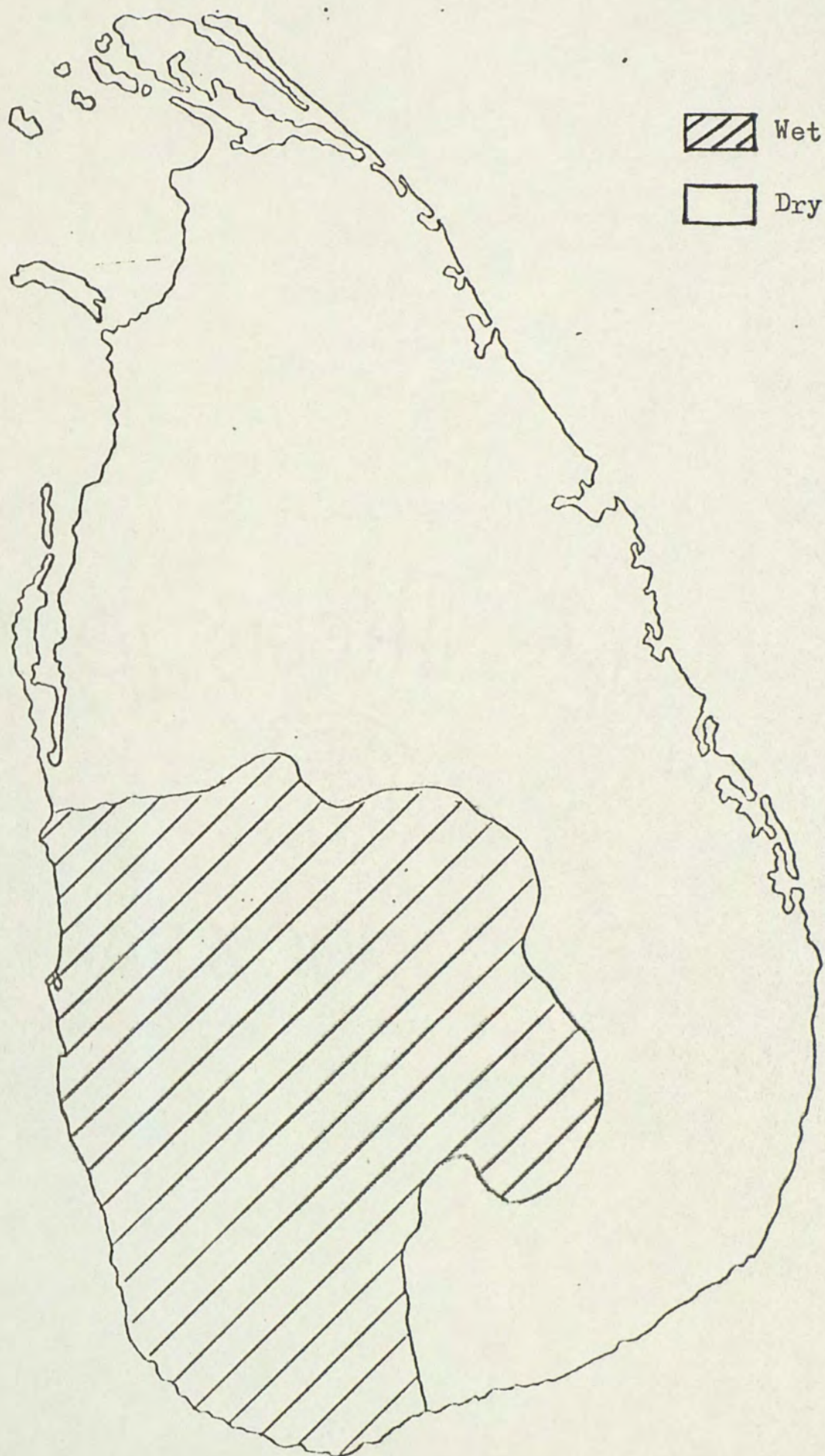


Fig. 2-1. Sri Lanka's Wet and Dry Zones

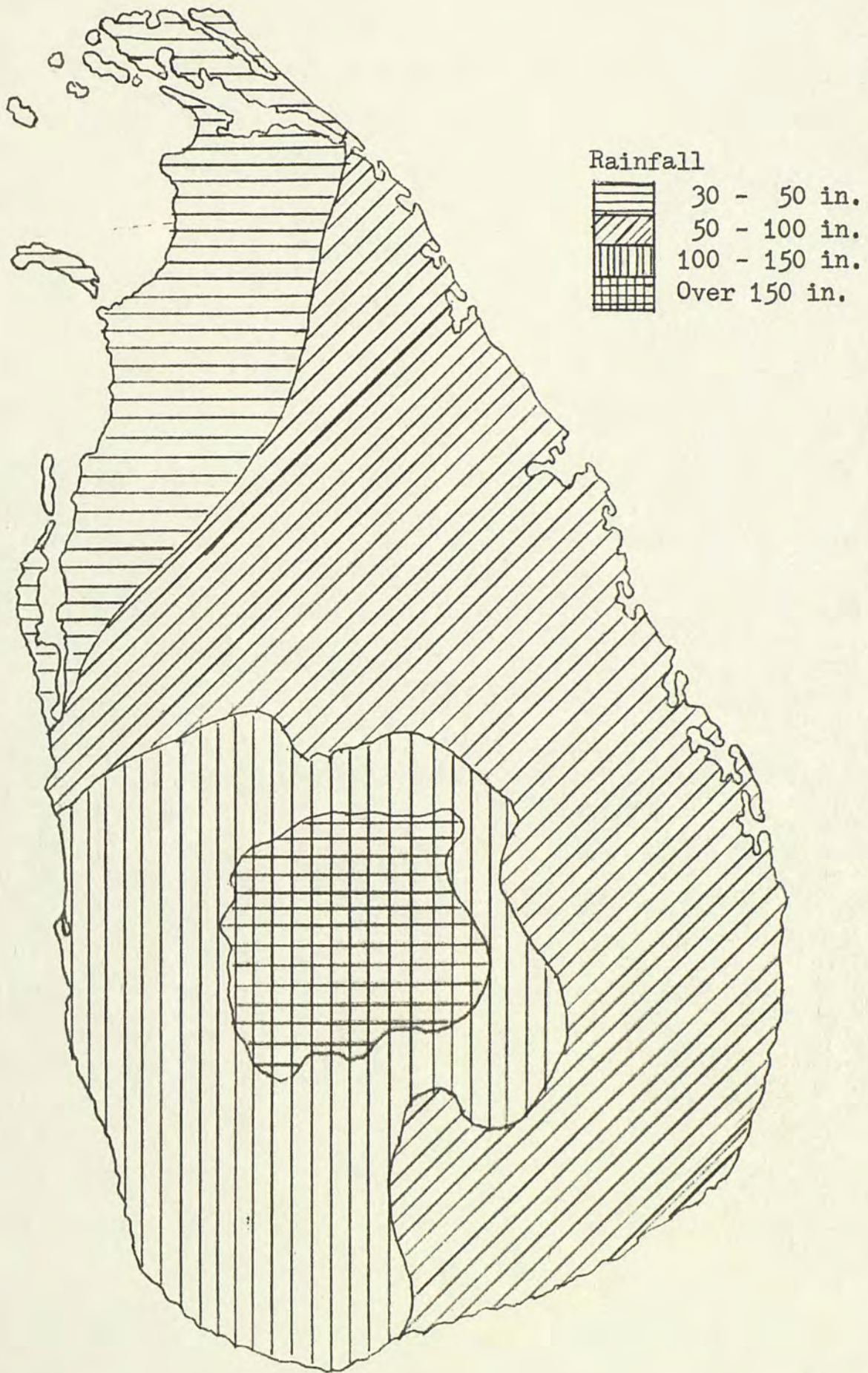


Fig. 2-2. Srilanka's Rainfall

Soon after the independence, the need for industrial development became essential, at least to cater to the growing local consumption. With this basic idea Srilanka's government pioneered in creating a number of state owned industrial complexes which are located in various areas of the island. Since most of the industries were water consuming the industrial complexes had to be located close to the waterways. Figure 2-3 shows the waterways of Srilanka and Figure 2-4 shows the various locations of the industrial complexes of Srilanka. Textile and pulp and paper mills were the first industries which came into operation in Srilanka.

Pollution due to industrial wastes is just beginning in the coastal belts, especially in the low lying areas. Waterways close to the textile and pulp and paper complexes are already polluted and the toxic effect of the pollutants on fish, and in coloring the waters to unaesthetic levels, is becoming an occasional problem.

Solving industrial pollution problems at the bud is much easier than trying to solve them later after they grow up. Suitable legislative backing, together with expert know-how on the technicalities inter-connecting biological, chemical, and engineering aspects, could lead to a satisfactory state of affairs. Pollution control legislation for Srilanka essentially should carry the following important descriptions and specifications which are similar and/or parallel to important aspects of legislation in United States of America at state, federal, and county levels (3).

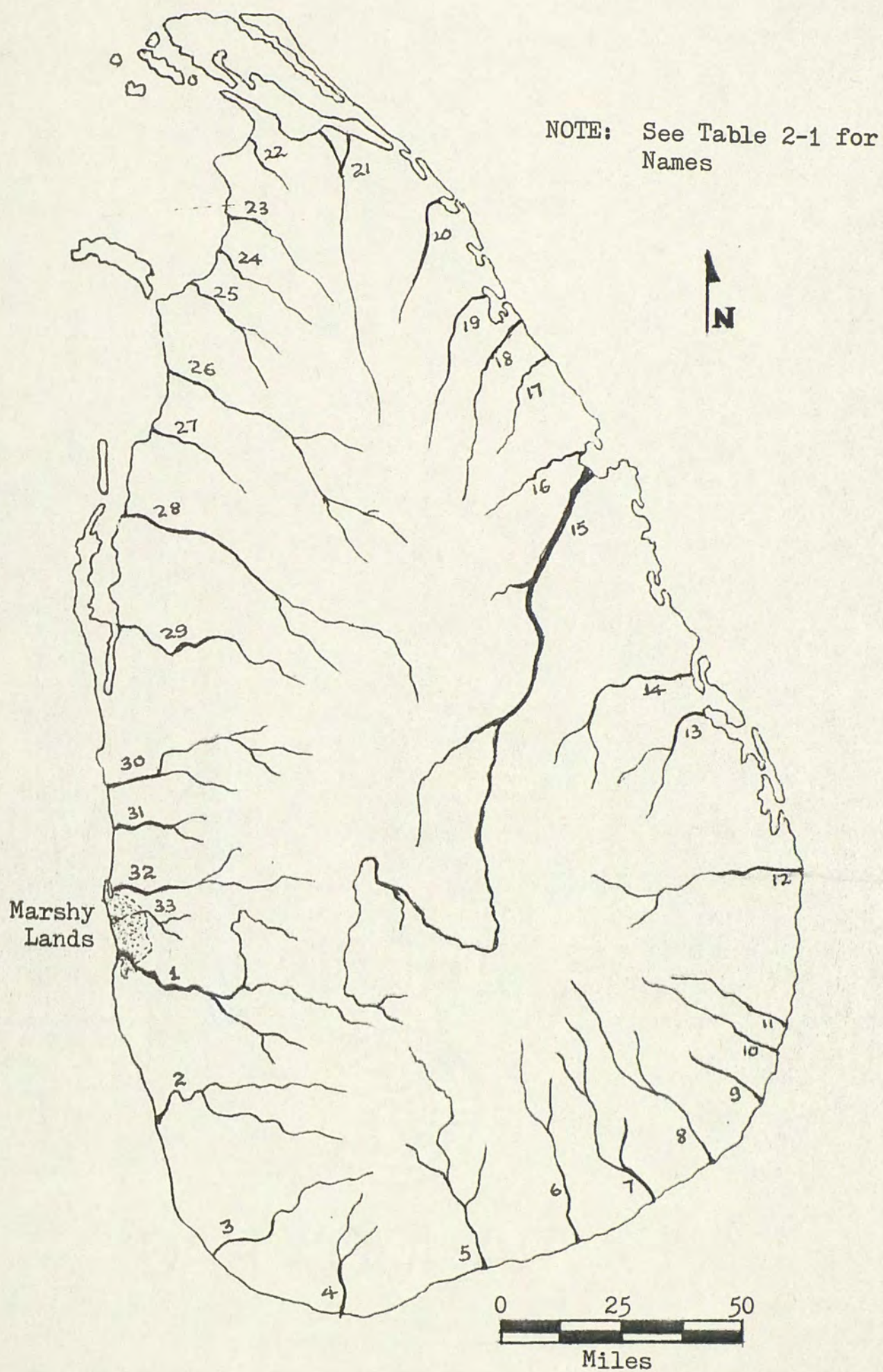


Fig. 2-3. Srilanka's Rivers and Waterways

TABLE 2-1
 NAMES OF RIVERS AND WATERWAYS SHOWN
 ON FIGURE 2-3

No.	Name	River or Small River
1	Kelani Ganga	River
2	Kalu Ganga	River
3	Ging Ganga	River
4	Nilwala Ganga	River
5	Walawe Gange	River
6	Kirindi Oya	Small River
7	Menik Ganga	River
8	Kumbukkan Oya	Small River
9	Vila Oya	Small River
10	Heda Oya	do
11	Karunda Oya	do
12	Gal Oya	do
13	Mundbniaru	do
14	Maduru Oya	do
15	Mahaweli Ganga	River
16	Kantalei Ganga	Small River
17	Pankulamaaru	do
18	Yaan Oya	do
19	Maa Oya	do
20	Pae Aaru	do
21	Kanagayan Aaru	do
22	Mandakelaaru	do
23	Pali Aaru	do
24	Parangi Aaru	do
25	Thee Aaru	do
26	Malwatu Oya	do
27	Moderagum Oya	do
28	Kala Oya	do
29	Mee Oya	do
30	Deduru Oya	do
31	Karamal Oya	do
32	Maha Oya	do
33	Attanagalu Oya	do

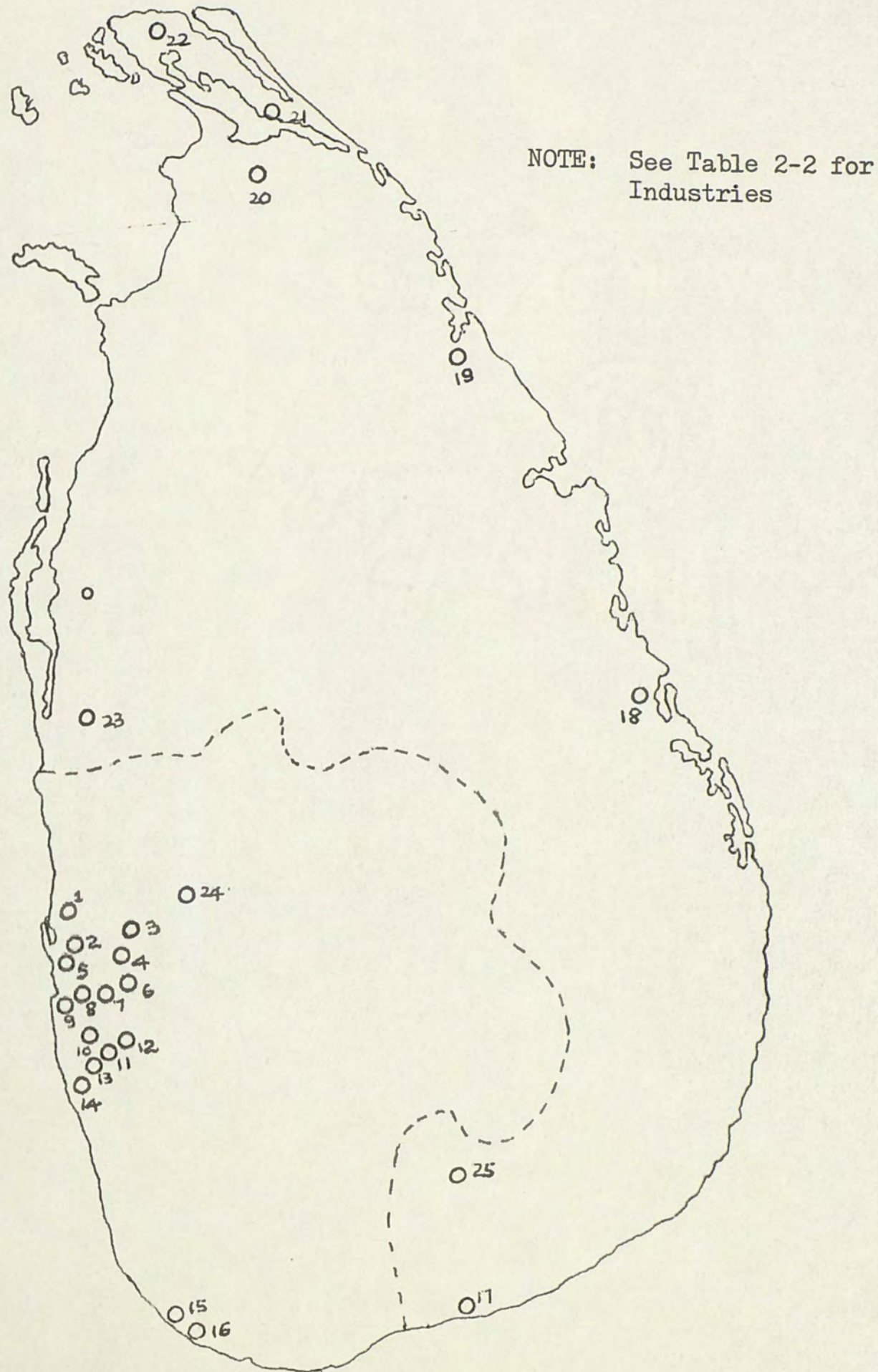


Fig. 2-4. Location of Srilanka's Industries

TABLE 2-2

INDUSTRIES AND LOCATIONS FOR FIGURE 2-4

No.	Industry and Location
1	Ceramics (Negombo)
2	Oils and Fats (Seeduwa)
3	Textiles (Veyangoda)
4	Hardware (Yakkala)
5	Small Industries State (Ekala)
6	Textiles (Pugoda)
7	Tires (Kelaniya)
8	Tanning (Mattakkuliya)
9	Grain Milling (Mutdval)
10	Fruit Canning (Narahenpita)
11	Ayurvedic (Herbal) Medicines (Nawinna)
12	Iron and Steel (Oruwala)
13	Ceramics (Piliyandala)
14	Woodwork (Moratuwa)
15	Hardboard (Gingtota)
16	Cement (Galla)
17	Common Salt (Hambantota)
18	Pulp and Paper (Valachchene)
19	Ilmenite (Pulmuddei)
20	Chemicals (Paranthan)
21	Common Salt (Elephant Pass)
22	Cement (Kankasanturai)

Purpose of the Legislation

To enhance the value of Srilanka's water resources and to establish a national policy for the prevention, control and abatement of water pollution, the Rajya Sabha (parliament) of Srilanka has declared its policy to recognize, preserve, and protect the primary responsibilities and rights of Srilanka's government in preventing and controlling water pollution, to support and aid technical research relating to the prevention and control of water pollution, and to provide technical services and financial aid to government agencies, semi-government agencies, and municipalities in connection with prevention of water pollution by creation of a legislative authority.

A Srilanka water pollution control commission is to be created to be the only government agency with legal responsibilities with respect to water pollution (but not extending to any other aspects of water resources).

Powers of the Commission

The commission should be given eight broad powers. They are: to investigate and study all problems concerned with improvement and conservation of Srilanka's waters; to develop programs pertaining to the treatment and disposal of sewage and industrial wastes; to propose remedial measures for the abatement of pollution, insofar as practical means are available; to advise the industries and municipalities with respect to the control of pollution; to establish stream standards in relation to their best usage as shall be in the public

interest; to receive and examine plans and applications for permits to treat and dispose of sewage and industrial wastes; to investigate and exercise surveillance on the discharge of pollution being made under a permit; and to issue orders directing abatement of pollution within a reasonable specified time.

Definition of Pollution

Pollution means any alteration of the physical, chemical, or biological properties of the waters of Srilanka, including change of temperature, taste, or odour of the waters, or the addition of any liquid, solid, radioactive, gaseous, or other substances to the waters or the removal of such substances from the waters harmful to the public health, safety, or welfare, or which renders the waters harmful or substantially less useful for domestic, municipal, industrial, agricultural, recreational, or other lawful uses or for animals, birds, or aquatic life.

Policy on Industry

Any person proposing to discharge wastes to surface or ground waters of Srilanka must apply to the commission for a permit and submit such basic information as the general description of the proposed operation, the characteristics of the effluent to be discharged, and any other information the commission deems necessary. Permits will not be of a permanent nature but will be extended from time to time under justification of the cause.

Penalty for Pollution

If the commission finds a person or municipality to be causing pollution or a threat of pollution, it has the right to issue, through the high court of the district in which the violation takes place, an injunction order to cease and desist polluting practices.

If a party is found guilty of violating any provision of the act or does not obey a court injunction order the said party shall be guilty of a misdemeanor and is therefore to be punished as provided by law. Each day of continued violation after conviction is a separate offense.

Water Use Classification and Criteria

Classification of water resources are to be made into six categories: (a) drinking water supplies, (b) recreation, (c) fishing, propagation of fish, shell fish, game and other aquatic life, (d) agricultural, (e) industrial, and (f) navigation.

General criteria for all waters in the territories of the Republic of Srilanka:

a. All waters shall be free from materials associated with municipal or domestic sewage, industrial waste or any other waste which will settle to form sludge deposits that become putrescent, unsightly, or otherwise objectionable.

b. All waters shall be free from oil, scum, and floating debris associated with municipal or domestic sewage, industrial or other discharges in amounts sufficient to be unsightly or to interfere with legitimate water uses.

c. All waters shall be free from material related to municipal, industrial or other discharges which produce turbidity, color, odour, or other objectionable conditions which interfere with legitimate water uses.

d. All water shall be free from toxic, corrosive, acidic and caustic substances discharged from municipalities, industries or other sources, in amounts, concentrations or combinations which are harmful to humans, animals, and aquatic life.

e. The maximum permissible concentration of radio-nuclides in the waters of the Republic of Srilanka must conform to the limits which are to be cited by the Srilanka water pollution control commission from time to time.

Specific Criteria for Classified Water Usage
in the Republic of Srilanka

Drinking Water Supplies

a. Those waters approved by Srilanka Water Supply and Drainage Board and requiring only approved disinfection and meeting the requirements specified by the Srilanka Water Supply and Drainage Board or water approved by the Srilanka Water Supply and Drainage Board for human consumption and food processing or for any other use requiring waters of a lower quality.

Bacteria

Fecal coliform not to exceed a mean of 50 per 100 milliliters (MPN) based on at least four samples taken over a 30 day period and not to exceed 200 per 100 milliliters in more than five percent (5%) of the samples in any 90 day period.

Floating solids, settleable solids, sludge deposits or any taste, odour, or odour producing substances.

None associated with any waste discharge.

Sewage - industrial or other waste.

None.

b. Those raw water supplies requiring approved treatment to meet the requirements of the Srilanka Water Supply and Drainage Board which are approved by the Srilanka Water Supply and Drainage Board for human consumption and food processing; or for any other use requiring water of a lower quality.

Bacteria

Fecal coliform not to exceed a mean of 5,000 per 100 milliliters (MPN) based on at least four samples taken over a 30 day period and not to exceed 20,000 per 100 milliliters in more than five percent (5%) of the samples taken in any 90 day period.

Dissolved Oxygen

Not less than 4.0 milligrams per liter at any time; a minimum of 5.0 milligrams per liter at all times for waters designated as trout streams by the Department of Game and Wildlife.

pH

Within the range of 6.0 - 8.5.

Temperature

Not to exceed 93.2°F (34.0°C) at any time and not to be increased more than 10°F above intake temperature. In streams designated as trout waters by the Department of Game and Wildlife, there shall be no elevation or depression of natural stream temperatures.

No material or substance in such concentration that, after treatment, would exceed the requirements of "Public Health Service Drinking Water Standards" of the Srilanka Water Supply and Drainage Board.

Recreation

General recreation activities such as water skiing, boating, and swimming, or for any other use requiring water of a lower quality. These criteria are not to be interpreted as condoning water contact sports in proximity to sewage or industrial waste discharges regardless of treatment requirements imposed on such waters.

Bacteria

Fecal coliform not to exceed a mean of 1,000 per 100 milliliters (MPN) based on at least four samples taken over a 30 day period, and not to exceed 4,000 per 100 milliliters in more than five percent (5%) of the samples taken in any 90 day period.

Dissolved Oxygen

Not less than 4.0 milligrams per liter except that those streams designated as trout waters by the State Game and Fish Commission must have a minimum of 5.0 milligrams per liter at all times.

pH

Within the range of 6.0 - 8.5.

Toxic Wastes and Other
Deleterious Materials

None in concentrations that would harm man, fish and game or other beneficial aquatic life.

Temperature

Not to exceed 93.2°F (34.0°C) at any time and not to be increased more than 10°F above intake temperature. In streams designated as trout waters by the Department of Game and Wildlife, there shall be no elevation or depression of natural stream temperatures.

Fishing, Propagation of Fish, Shellfish, Game and Other Aquatic Life,
or Any Other Use Requiring Water of a Lower Quality

Dissolved Oxygen

A minimum of 5.0 milligrams per liter at all times for streams designated as trout waters by the State Game and Fish Commission; a minimum of 4.0 milligrams per liter

at all times for waters supporting warm water species of fish.

pH Within the range of 6.0 - 8.5.

Bacteria Fecal coliform not to exceed a mean of 5,000 per 100 milliliters (MPN) based on at least four samples taken over a 30 day period and not to exceed 20,000 per 100 milliliters in more than five percent (5%) of the samples in any 90 day period.

Bacteria (applicable only to shellfish to be commercially harvested) Total coliform group not to exceed a median MPN of 70 per 100 milliliters, and not more than 10 percent (10%) of the samples shall exceed an MPN of 230 per 100 milliliters for a 5-tube decimal dilution test (or 330 per 100 milliliters where a 3-tube decimal dilution is used) in those areas most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions.

Temperature Not to exceed 93.2°F (34.0°C) at any time and not to be increased more than 10°F above intake temperature. In streams designated as trout waters by the Department of Game and Wildlife, there shall be no elevation or depression of natural stream temperature.

Toxic Wastes and Other Deleterious Materials None in concentrations that would harm man, fish and game or other beneficial aquatic life.

Agricultural

For general agricultural uses such as stock watering and irrigating; or for any other use requiring water of a lower quality.

Bacteria Fecal coliform not to exceed a mean of 10,000 per 100 milliliters (MPN) based on at least four samples taken over a 30 day period and not to exceed 40,000 per 100 milliliters in

more than five percent (5%) of the samples in any 90 day period.

Dissolved Oxygen

A daily average of 3.0 mg/l and no less than 2.5 mg/l at any time.

pH

Within the range of 6.0 - 8.5.

Temperature

Not to exceed 93.2°F (34.0°F) at any time and not to be increased more than 10°F above intake temperature.

Toxic Substances and Other
Deleterious Materials

None in concentrations or amounts that would interfere with or adversely effect uses for general agricultural purposes or would prevent fish survival.

Industrial

For processing and cooling water with or without special treatment; for any other use requiring water of a lower quality.

Dissolved Oxygen

A daily average of 3.9 mg/l and not less than 2.5 mg/l at any time.

pH

Within the range of 6.0 - 8.5.

Toxic Substances and Other
Deleterious Materials

None in concentrations that would prevent fish survival or interfere with legitimate and beneficial industrial uses.

Temperature

Not to exceed 93.2°F (34.0°C) at any time and not to be increased more than 10°F above intake temperature.

Navigation

To provide for commercial ship traffic and protection of seamen or crews.

Bacteria

Fecal coliform not to exceed a mean of 10,000 per 100 milliliters (MPN) based on at least four samples taken over a 30 day period and not to ex-

ceed 40,000 per 100 milliliters in more than five percent (5%) of the samples in any 90 day period.

Dissolved Oxygen

A daily average of 3.9 mg/l and not less than 2.5 mg/l at any time.

pH

Within the range of 6.0 - 8.5.

Toxic Substances and Other
Deleterious Materials

None in concentrations or amounts that would damage vessels, prevent fish survival, or otherwise interfere with commercial navigation.

Temperature

Not to exceed 93.2°F (34.0°C) at any time and not to be increased more than 10°F above intake temperature.

Procedure for Issuing of Permits

When petitioning the Water Pollution Control Commission for a permit to treat and discharge industrial wastes into waterways, besides the engineering diagrams, etc., the plans must also include the following information: type industry, kind and quantity of finished product; amount of wastes and sources; quantity of other discharges; description of waste including chemical analysis; amount and kinds of chemicals used in process; proposed solution to the problem; cost estimates for construction operation and maintenance; and sufficient charts, tables, calculations, basis of design data, and graphs to make the report readily understandable.

CHAPTER III

POLLUTION PARAMETERS

Industrial wastewaters, in general, are associated with chemical and biological constituents in dissolved, suspended or undissolved form. Radioactive and thermal effects are not excluded. Pollution parameters, and how and why these are important in industrial waste treatment, will be briefly indicated with reference to the EPA publications on industrial point sources (4,5,6).

Biochemical Oxygen Demand

BOD is a measure of the oxygen consuming capabilities of organic matter in a sample of wastewater. Organic constituents in sewage, in the process of decomposition, consume most of the dissolved oxygen in a water. Once the amount of dissolved oxygen is used up, these waters generate gases like methane or hydrogen sulfide.

High BOD values indicate the presence of decomposing matter and subsequent high bacterial counts, finally lowering the quality of the water and its potential uses. Aquatic organisms utilize dissolved oxygen for their growth and living. Low or reduced dissolved oxygen levels have been shown to interfere with fish populations through delayed hatching of eggs, reduced size, vigor of embryos, production of deformities among young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxic

cants, reduced food efficiency, growth rate, and reduced sustained swimming speed. Fish food organisms also are affected by lower dissolved oxygen values. Total lack of dissolved oxygen in water due to high BOD values results in the eradication of fish and all other aerobic microorganisms exposed to the water, finally leading to anaerobic conditions. Textile, pulp and paper, food processing, and dairy industries all have high BOD values.

Chemical Oxygen Demand

This is a measure of the potential oxygen consumption of a wastewater sample by chemical reaction. Under COD the amount of oxygen consumed by non-biological constituents also is assessed. Differences between COD and BOD values are a good assessment of the amount of pollutants which are not biodegradable. COD will be an indicator of the amount of pollution's effect over and above the BOD values.

Total Suspended Solids

Industrial waste could contain sand, silt, and clay as inorganic constituents and materials like grease, oil, tar, vegetable fats, various fibers, sawdust, hair, and various other undissolved matter as organic constituents.

Most of these solids may settle out, rapidly forming bottom deposits in water or waste streams. This blanket action destroys fish, food, benthic organisms and spawning grounds of fish. Deposits containing organic materials deplete bottom oxygen contents such that anaerobic conditions prevail.

Presence of suspended solids in waters is not desirable by any of the waters used by such industries as textile, pulp and paper, brewery, dairy, laundry, dyeing, and photography, or for cooling systems and power plants, due to various maleffects like foaming in boilers, encrustations on equipments exposed to water, and so forth. Suspended matter in water prevents and cuts out the direct penetration of sunlight onto the bottom of the water streams impoundments, finally reducing the photosynthetic activities.

Coliform Organisms

Fecal coliforms are considered as an indicator of fecal pollution since they originate from the intestinal tract of warm blooded animals. In pulp and paper industrial effluents, the most valid microbiological pollution parameter is reported to be the fecal coliform test. Excessive densities of fecal coliforms, and more specifically *Klebsiella pneumoniae*, as measured by the fecal coliform test, in pulp and paper mill effluents are significant. *Klebsiella* can complicate *E. coli* detection, they can be pathogenic, and they are coliforms by definition. *Klebsiella* reflect high nutrient levels in pulp and paper mill wastes. With adequate treatment for reduction of nutrients, densities of *Klebsiella* and also total coliforms should be significantly reduced. When the fecal coliform count exceeds 2,000 per 100 milliliters there is a high correlation with increased numbers of both pathogenic viruses and bacteria.

Many microorganisms, pathogenic to humans and animals, may be carried in surface water, particularly that derived from effluent

sources which find their way into surface water from municipal and industrial wastes. The diseases associated with water include bacillary and amoebic dysentery, Salmonella gastroenteritis, typhoid and paratyphoid fevers, leptospirosis, cholera, vibriosis, and infectious hepatitis. Recent studies have emphasized the value of fecal coliform density in assessing the occurrence of Salmonella, a common bacterial pathogen in surface water. Field studies involving irrigation water, field crops, and soils indicate that when the fecal coliform density in stream waters exceeded 1,000 per 100 milliliters, the occurrence of Salmonella was 53.5 percent.

Colour

This is defined as either "true" or apparent colour. Removal of turbidity before colour measurements has been recommended in the true colour measurements (4). Apparent colour includes the colour due to substances in solution as well as that due to suspended and colloidal matter.

Colour in textile industry wastes results from equipment washing, textile wash water, and unconsumed dyes from dyeing steps. In the pulp and paper industry, the cooking liquors and pulp washing stages generate colour. Colour has the following detrimental effects upon receiving waters: (a) retardation of transmission of sunlight thereby reducing the growth of the aquatic community depending on photosynthesis, (b) alteration of stream waters to make them aesthetically unacceptable, (c) coloured waters are not acceptable for drinking as well as for industrial use, (d) colour bodies form chemical complexes with

metallic ions like iron or copper which are essential for the growth of organisms in waterways. Some complexes have been found to have a direct impact on some of the lower classes of organisms in the aquatic community thereby reducing the productivity of the receiving waters, (e) colour in waters affects fish movement and fish productivity, (f) colour bodies exert a long term (29 to 60 days up to 100 days) BOD which is not accounted for by the normal five-day BOD test (5).

Techniques for measuring colour vary according to the industry. The textile industry uses the analytical methods developed by the American Dye Manufacturing Institute (4), and the pulp and paper industry uses the analytical methods specified by the National Council for Air and Stream Improvement in the U.S (5).

Turbidity

Turbidity is an expression of the optical property of a fine suspended matter in a sample of water. The suspended matter may be clay, silt, finely divided organic or inorganic matter, plankton, and other microscopic organisms. Suspended matter causes light to be scattered and absorbed rather than transmitted in straight lines. Most of the biological treatment processes are capable of removing turbidity.

Temperature

Temperature is one of the most important and influential water quality characteristics. Being a prime regulator of natural processes, within the water environment it governs most of the physio-

logical functions in organisms and acts directly or indirectly with other water quality constituents, affecting aquatic life with every change. These effects include variation of chemical reaction rates, enzymatic functions, molecular movements, molecular exchanges between membranes within and between the physiological systems, and the organs of aquatic flora and fauna. Temperature determines the types of species present in a water body. It activates the hatching of young, regulates their activity, and stimulates or suppresses their growth and development. Thermal pollutants could attract fish and may kill them suddenly due to variations in temperature. Reproduction cycles of fish may change, and spawning may not occur at all at high temperatures.

Textile, pulp, grain milling, and similar industries using thermal processes are the common causes of industrial thermal pollution.

Ammonia

Ammonia is a common product of the decomposition of organic matter. Industrial use of ammonium compounds results in the presence of ammonia in industrial wastewaters, at high pH levels. Ammonia in the presence of dissolved oxygen is converted into nitrates and nitrites by nitrifying bacteria. Nitrates are considered to be among the poisonous ingredients of mineralized waters, with potassium nitrate being more poisonous than sodium nitrate. Excess nitrates cause irritations of the mucous linings of the gastrointestinal tract and the bladder. The consumption of one liter of water containing 500 mg/l of nitrate can cause symptoms of diarrhea and diuresis. In-

fant methemoglobinemia, a disease characterized by certain specific blood changes and cyanosis, may be caused due to high nitrate concentrations in the water used with infant feeding. The presence of excessive nitrates is not acceptable for drinking water as well as for industrial uses. Ammonia and nitrates are associated with suffocation of fish and eutrophication of lakes and waterways.

Phosphorous

Phosphorous is usually considered as a limiting factor for plant growth. Increased phosphorous content has increased the consumption of nutrients for plant growth, and is associated with excessive algal and weed growth. Phosphorous in elemental form is toxic and subject to bioaccumulation. Corn dry milling and parboiled rice production are found to generate high concentrations of phosphorous, ranging from 30 to 65 mg/l (7).

pH, Acidity, and Alkalinity

Toxicity of some compounds is increased with variations in pH. Metallo cyanide toxicity increases a thousand fold with a drop of 1.5 pH units. Ammonia with high pH values is found to be more lethal. The lacrimal fluid of the human eye has a pH of about 7.0. A deviation from the normal value may result in eye irritations to swimmers and water users.

Toxic Metals and Metal Traces

Silver, cadmium, chromium, copper, mercury, lead, antimony, tin, tellurium, zinc, barium, bismuth, iron, manganese, molybdenum,

titanium and uranium are reported to be metals which have high pollution potential if present in water (8). Industrial wastes in general have associated metallic constituents. These toxic constituents are found to be hazardous to living organisms if present at concentrations above specified dosages (8).

Sulfides

Reduction of sulfides in natural waters forms hydrogen sulfide gas, which is toxic, odorous, and corrosive. Concentrations of hydrogen sulfide even less than 0.002 mg/l impart objectionable tastes and odour. Sulfides are toxic to aquatic life. Sulfide corrosion of metal and cement structures are additional problems which make the presence of sulfides unacceptable. Organic sulfur and sulfide dyes are common in the waste flow from textile dye houses.

Phenols

Phenols are famous for their unpleasant tastes and odour in waters. They are toxic. Textile processing, petroleum, coke and chemical industries, and wood distillations (4) are the sources of phenolic industrial wastes. Chlorophenols produce unpleasant tastes in fish flesh, which destroys the recreational value of fish.

Oils and Greases

Oils and greases in water form emulsions which adhere on gills of fish, and on algae and other plankton, creating nuisances in waterways. Floating oils prevent reaeration of the waters. Deposition of oil layers at the bottom of waterways inhibit normal benthic

growth, thereby interrupting aquatic food chains.

Water soluble components of oils and greases may impart taint flavours to fish flesh, or become toxic to fish life. Layers of oil and grease may even interfere with the photosynthetic activity.

CHAPTER IV

THEORIES AND METHODS OF INDUSTRIAL
WASTEWATER TREATMENT

Wastes generated from one industry differ from others. Sometimes even within the same industry methodologies of production differ. A general view of common theories of industrial wastewater handling, together with a brief review of the methodologies used in industrial wastewater treatment, are given in this chapter.

Minimization of waste production could be achieved by reducing the volume of waste produced. This could be achieved by a number of methods like classification of wastes, conservation of wastewater, changing production to decrease waste generation, reusing industrial effluents or by the use of treated municipal sewage in industry, and elimination of sudden discharges of waste loads to waterways or sewers (1).

Classification of wastewaters avoids the mixing of wastes from different stages which could be generally classified into waste, from manufacturing processes, waters used in cooling activities or in any other thermal process, and wastes from sanitary uses. By this means the polluted waters could be treated according to the need.

Conservation of wastewater in closed systems not only conserves water but also conserves the chemicals used by the industry. Recycling of effluents from various stages of treatment commonly is used in paper and textile industries. In choosing equipment for industries,

due recognition should be given to the water economy. Changing production to decrease wastes is practiced by most industries during shortages of water, and is found to be effective. In addition to using the water saving methods of production, good housekeeping and preventive maintenance are two other aspects of importance.

Reuse of industrial effluents from one stage for use in the same stage, saves the chemicals used at the same time. Treated municipal waters are quite acceptable for some industries not involved with food or beverage production.

Sudden discharge of wastewaters may imbalance the wastewater treatment plant. A uniform discharge, not to unbalance the capacity of the receiving system, is sometimes known as the elimination of batch or slug discharges.

Waste strength reduction could be achieved by practicing methods such as "in process" changes, equipment modification, segregation of wastes, by-product recovery, proportioning of wastes, and monitoring waste streams.

"In process" changes cannot be suggested unless the wastewater engineer is conversant with the various processes carried out by the industry. A critical evaluation of the production techniques together with experience on the recent advances of technology could be helpful in successful results. Modification of already available equipment, together with earlier mentioned good housekeeping techniques, will lead to more economical production and to savings on expenditures in wastewater treatment.

Segregation of wastes is useful where chemicals used in different stages of the same industry react with each other, producing complicated products which are difficult to treat. In handling toxic wastes this method is useful.

By-product recovery is very well used in a number of industries. Wastes produced from one industry are used as raw materials for another industry, thereby lowering the waste loads and leading to treatable effluents.

Proportioning of concentrated wastes into the sewer lines in some cases reduces the total waste strength up to the point of minimum final effluent treatment. In handling the wastewaters from small industrial complexes this method may be adequate.

Monitoring of waste streams uses remote sensing devices to indicate variations exceeding the limits of pollutants. Redirecting the flow and varying the chemical feeds is useful in remedying any mistakes or malfunctions occurring in a wastewater treatment plant.

Neutralizing of excessive acidity or alkalinity in wastes is carried out by the use of methods such as mixing wastes to obtain a neutral pH, passing acid wastes through beds of limestone, mixing acid wastes with lime slurries or dolomite slurries, adding suitable proportions of concentrated solutions of caustic soda or soda ash to acid wastes, blowing boiler waste flue gases through alkaline wastes, adding compressed carbon dioxide to alkaline wastes, producing carbon dioxide in alkaline wastes, and adding acid to alkaline wastes.

Equalization and proportioning commonly is used to handle wastes of toxic chemical composition. Equalization basins or tanks produce

more uniform pollution parameters for the wastes by allowing physical and chemical interactions to take place. Some of these basins level off the peak loadings and are equipped with aeration and proper mixing facilities. Equalized wastes from some industries are suitable for discharging to the sewer lines under suitable proportioning.

Methods of Wastewater Treatment

Removal of floating particles and large sized suspended solids are carried out by racks, screens, and grit chambers. Floating oils and greases are removed by grease or oil traps. Racks and screens separate particles directly from the waste stream. Removal of particles from these units are either carried out by means of vibration (mechanical, manual), or by the use of steam and compressed air. Grit chambers are used to separate solids which are suspended and are not removed at the rack and screening stage, but retained in the form of heavy suspensions. Grease traps are used to separate fats and oils present as a floating scum. Sedimentation uses the settling effect of particles in a wastewater, and is mostly aided by a chemical flocculation stage for the formation of heavier flocs. Flotation converts suspended substances, together with colloidal, emulsified, and dissolved substances, into floating matter. Flotation units either use violently agitated, vacuum, air bubble or pressure flotation techniques, which are found to be very effective in suspended solid removal. Removal of inorganic dissolved solids from waste loads is carried out by methods like evaporation, dialysis, ion exchange, algae, reverse osmosis, and chemical precipitation.

Removal of organic dissolved solids is carried out by biological processes such as lagooning in oxidation ponds, anaerobic lagooning, activated sludge treatment, modified aeration, dispersed growth aeration, contact stabilization, high rate aerobic treatment, trickling filtration, spray irrigation, wet combustion, anaerobic digestion, mechanical aeration systems, foam phase separation, brush aeration and subsurface disposal.

Table 4-1 shows the removal efficiencies of sedimentation and biological methods in the removal of metal traces at 10 ppm level.

Activated carbon in various forms is used in the removal of toxic chemicals and colour from wastewaters. The Table 4-2 and 4-3 show the toxicant removal capacity of activated carbon in connection with various concentrations of toxic chemicals.

Microstraining is used in separation of special small sized particles or fibers. Anaerobic sludge digestion is used as a method of producing methane gas at temperatures around 35°C (9). Final sludge disposal methods include vacuum filtration or centrifuging before being used as fertilizer, in land disposal, or in sanitary landfill operations.

TABLE 4-1

REMOVAL EFFICIENCIES OF SEDIMENTATION AND BIOLOGICAL
METHODS IN THE REMOVAL OF METAL TRACES
IN SEWAGE TREATMENT (9)

Metal	Sedimentation Only (%)	Sedimentation Followed by Biological Treatment (%)
Lead	50	90
Copper	40	80
Zinc	60	50
Chromium	25	50
Nickel	30	30

TABLE 4-2
ADSORPTION BY ACTIVATED CARBON (10)

Chemical	Initial Concentration (ppm)	Carbon Dosage	Residual Concentration (ppm)	Percent Removal
Phenol	1000	10X	3	99
	500	10X	2	99
	100	10X	1	99
Acetone	1000	10X	400	60
Cyanohydrin	200	10X	110	45
	100	10X	70	30
Methanol	1000	10X	830	17
	200	10X	132	33
	15	10X	10	33
Acrylonitrile	1000	10X	490	51
	100	10X	72	28
Chlorine	1000	10X	0.05	99
	500	10X	0.05	99
	200	10X	0.15	99
	100	10X	0.05	99
Pyridine	1000	10X	145	86
	500	10X	71	86
Isoprene	1000	10X	110	89
	500	10X	110	78
Butanol	1000	10X	249	75
	500	10X	163	67
	100	10X	52	48
Benzaldehyde	1000	10X	9	99
	500	10X	6	99
	100	10X	2	98
Benzene	500	10X	27	95
	250	10X	23	91
	50	10X	20	60
Xylene	200	10X	29	86
	100	10X	32	68
Styrene	200	10X	6	97
	100	10X	7	93
	20	10X	9	55

TABLE 4-3

CARBON ADSORPTION OF Mn, Cu, Ni, Cr, Hg AND Pb (10)

Heavy Metal Tested	Activated Carbon Dosage (ppm)	Residual Metal Concentration (ppm)	Percent Removal	Test Chemical
Mn ⁺²	0	100	0	MnCl ₂
	500	99	1	
	1,000	97	3	
	5,000	75	25	
	10,000	50	50	
Cu ⁺²	0	50	0	CuSO ₄
	500	46	8	
	1,000	45	10	
	5,000	13.5	73	
	10,000	1.8	96.4	
Ni ⁺²	0	100	0	NiCl ₂
	500	96	4	
	1,000	95	5	
	5,000	89.5	10.5	
	10,000	48	52	
Cr ⁺⁶	0	100	0	K ₂ Cr ₂ O ₇
	500	84	16	
	1,000	74	26	
	5,000	66	34	
	10,000	64	36	
Hg ⁺²	0	100	0	HgCl ₂
	500	1	99	
	1,000	1	99	
	5,000	1	99	
	10,000	1	99	
Cr ⁺³	0	100	0	CrCl ₃
	500	95	5	
	1,000	92.5	7.5	
	5,000	82.5	17.5	
	10,000	52.5	47.5	
Pb ⁺²	0	120	0	Pb(C ₂ H ₃ O ₂) ₂
	500	49	59.1	
	1,000	43	64.2	
	10,000	10.5	91.2	
Pb ⁺²	0	107	0	Pb(NO ₃) ₂
	500	93	13	
	1,000	88	17.7	
	5,000	17	84	
	10,000	7.5	93	

CHAPTER V

TEXTILE INDUSTRY WASTES AND WASTEWATER TREATMENT

The first state owned major textile mill of Srilanka came into operation in 1961. It originated as a spinning mill and later expanded into weaving, finishing, and printing stages. Today the Srilanka's National Textile Corporation owns two more mills, carrying out all the processing operations from raw cotton or synthetic fiber manufacture to the printed textiles. Medium sized mills carrying out one or more steps of the manufacturing process exist at various corners of the island mostly carrying out weaving, dyeing or printing. Wastewater treatment is still a neglected part of the industry mainly due to the nonexistence of pollution control regulations.

In general the raw materials used by the industry in Srilanka are cotton or synthetic fibers, or a blend of the two. Hydroelectric power is the prime energy source of the mills. Most of the cotton and synthetic fibers used are imported.

Cotton Textile Industry (3.4)

The cotton textile industry in general employs a number of physical and chemical operations in processing the raw cotton into the finished textiles. Figure 5-1 shows the various operations utilized by the industry. Raw cotton, imported or from the producing areas in the form of bales, is subjected to opening, picking, carding, combing, drawing, spinning, quilling, and winding. Operations are carried out

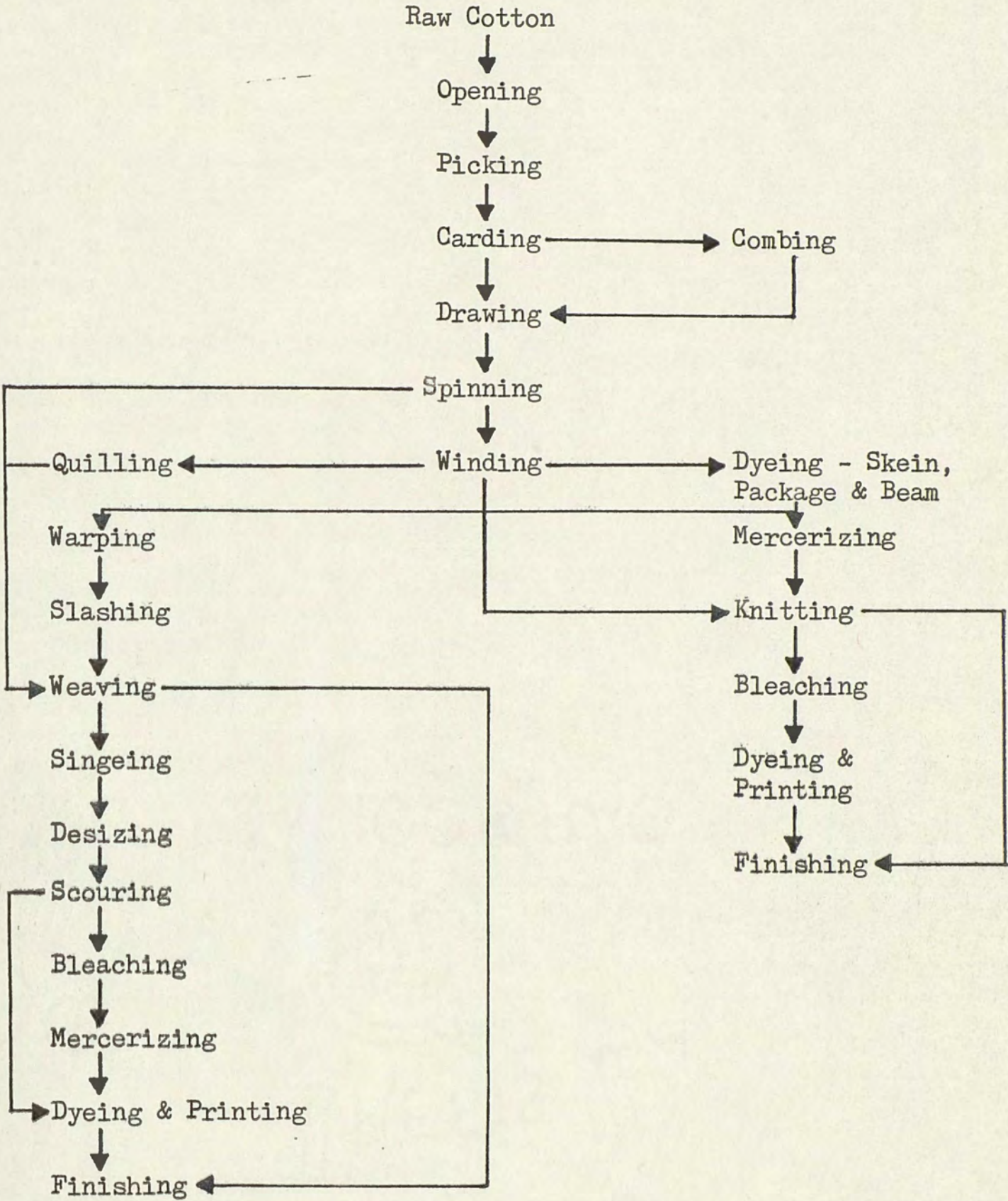


Fig. 5-1. Process Flow Sheet for Cotton Goods (3)

as dry processing operations where only solid wastes are generated.

Slashing is the first stage at which liquid treatment is involved. At this stage warp yarns are coated with sizing in order to give them tensile strength, to withstand the pressures exerted on them during the weaving operation. Table 5-1 shows the BOD values and the quantities of commonly used sizing agents of the industry.

Sizing agents normally used include starch, starch substitutes, polyvinylalcohols, polyacrylic acid, carboxymethyl cellulose, gelatin, glue, and gums. Cleaning of slasher boxes, rolls and makeup kettles is the source of pollution at these stages. Low liquid volume, associated with high BOD values, is a characteristic of the liquid wastes generated from this stage. Natural sizing agents have high BOD values but are biodegradable. Synthetic sizing agents have low BOD values and are not easily biodegradable. Starch generates quite high BOD values in comparison with other sizing agents.

A desizing operation removes the substances applied to the yarn, during the slashing operation, by hydrolysing the sizing into a soluble form by using either acid desizing or enzyme desizing. In acid desizing the fabrics are soaked in a solution of dilute sulfuric acid, at normal temperatures, for periods varying from 4 to 12 hours and then cleaned by rinsing. In enzyme desizing, complex organic compounds from natural products, or malt extracts, are used to solubilize the size. The desizing baths are maintained at temperatures ranging from 130°F to 180°F and a pH of 6 to 7.7 for periods of time varying from 4 to 8 hours. Due to the unstable nature of the resulting organic compounds produced, the baths have to be discarded after

TABLE 5-1

BOD of Commonly Used Sizing Compounds and Quantity
Used Per 1,000 lbs. of Fiber (3)

Compound	BOD (ppm)	Consumption lbs/1,000 lbs of Cloth
Corn Starch	810,000	477.0
British Gum	690,000	690.0
Methyl Cellulose	1,600	1.6
Carboxymethyl Cellulose	10,000	9.0
Polyvinyl Alcohol	1,600	1.6
Polystyrene	12,000	1.2

each operation. Desizing contributes the largest of the BOD values out of all cotton finishing operations.

Scouring is the next stage of operation at which the cotton wax and other noncellulosic constituents of the cotton are removed by hot alkaline detergents, caustic soda, soda ash, milk of lime, or soap solutions. In Srilanka, due to the availability of locally produced soaps, milk of lime, caustic soda and soda ash, the use of detergents is quite low. The scouring baths have pH values in the range 10 to 13, at boiling temperature. Although the strength of the alkali used at the start is in the range 1 percent to 5 percent, the waste liquor will have about 0.3 percent alkaline concentrations. Scouring is the second largest BOD contributor under the finishing operations of cotton textiles. After the scouring the final products are rinsed clear with hot and cold water to remove alkalinity.

Bleaching is used at the next stage to remove the yellowish colour of the cotton fiber and render it white. Bleaching chemicals mainly used include bleaching powder, sodium hypochlorite, and hydrogen peroxide. In hypochlorite bleaching, the fabric, after exposure to alkaline hypochlorite for a period of 4 to 12 hours, is neutralized by scouring with a solution of dilute hydrochloric acid or sulfuric acid, and then washed well with water. In using hydrogen peroxide for bleaching, the fabric, after desizing, is impregnated with a 2 to 3 percent solution of caustic soda and stored in a "j" box at 200°F for 1 hour. This operation replaces the batch method of kier scouring. The latter is used in some mills where scouring is carried out in the form of a batch, requiring the fabrics

to remain in the kier for a period of 12 hours. After the caustic scour, the fabrics are washed and then impregnated with a solution of hydrogen peroxide (2 to 3% concentrated) and again returned to a storage "j" box for one hour at 200°F. After the operation the fabrics are washed. Mercerization originally was used to impart a silky lustre to woven cotton goods, but, in addition to this property, the method also is used to improve or increase the dye affinity and the tensile strength of the fabrics. Cotton polyester blends do not use this method. The mercerization process exposes the fabric to a 15 to 24 percent sodium hydroxide solution at room temperature for periods varying between 1/2 to 3 minutes; then rinses the fabric in an acid mix to neutralize the alkalinity. The effluent from this stage is normally alkaline with low BOD and high suspended solids.

Dyeing or printing is the next operation. Here the fabrics are exposed to various chemicals in small volumes in batch process machines, or on continuous dyeing ranges in large volumes, or to printing roller machines. There are five important classes of dyes used in cotton fabrics - vat, developed, naphthol, sulfur, direct and aniline black.

Dyeing is carried out in aqueous dyebaths with pH values ranging from 6 to 12 at a temperature range of room temperature to boiling. Table 5-2 shows the chemicals present in cotton dye baths.

In the case of printing works, sometimes known as the colour shop, the printing rollers use printing paste. This paste contains dye, thickener, hygroscopic substances, dyeing assistants, water and other chemicals. After printing the fabrics are dried and then steamed

TABLE 5-2
CHEMICALS PRESENT IN COTTON DYE BATHS (3)

Dye Type	Chemicals Present
Aniline Black	Aniline hydrochloride, sodium ferrocyanide, sodium chlorite, pigments, soap.
Developed	Dye, penetrant, sodium chloride, sodium nitrate, hydrochloric acid, sulfuric acid, developer (beta naphthol), soap or sulfated soap or fatty alcohols.
Direct	Dye, sodium carbonate, sodium chloride, and wetting agent, or soluble oil or sodium sulfate.
Naphthol	Dye, caustic soda, soluble oils, alcohol, soap, soda ash, sodium chloride, sodium nitrate, sodium nitrite, sodium acetate.
Sulfur	Dye, sodium sulfide, sodium carbonate, sodium chloride.
Vat	Dye, caustic soda, sodium hydrosulfite, soluble oils, gelatine, perborate or hydrogen peroxide.

and after a fixing process in the case of basic colours, soaped and washed. In using the fast steam style colours the following series of operations is common in use: 1)Preparing the cloth by putting in a solution of castor oil together with olenic (soda or ammonium picenoleate, with or without the addition of tannic acid) 2)Drying the cloth before printing 3)Steaming in continuous or cottage type steamers 4) Fixing in $1/2$ to 2 percent solution of tartar emetic and chalk 5) Chroming in 1 percent solution of bichromate of soda. A well printed cloth is soaped and washed in a $1/10$ to $1/2$ percent solution of soap. Although the pollution load is low from this stage, the constituents will carry various toxic constituents from the dye stuffs, inclusive of traces of chromates.

Table 5-3 gives an extract of data listed in the state of the art review of textile waste treatment. The range of pollutional loads of various cotton textile wet processing is shown in this document. The ranges have been compiled from the values given by various authors in different studies. The wide variance in the data range is mainly due to the possible variations in using the technology and various chemicals.

Table 5-4 shows the characteristics of the wastes from the cotton wet processing operations and indicates the differences of the properties of effluents from various operations.

From the same reference (3), the waste load produced in treating 1000 pounds of cotton fabrics has composite waste characteristics generally assessed within the following limits:

TABLE 5-3
POLLUTION EFFECT OF COTTON PROCESSING WASTES (3)

Process	pH	Wastes (ppm)		Gallons Waste per 1,000 lbs Goods	Pounds BOD per 1,000 lbs goods	Pounds Total Solids per 1,000 lbs goods
		BOD	Total Solids			
Slashing, sizing yarn	7.0-9.5	620-2,500	8,500-22,600	60-940	0.5-5.0	47-67
Desizing	-----	1,700-5,200	16,000-32,000	300-1,100	14.8-16.1	66-70
Kiering	10-13	680-2,900	7,600-17,400	310-1,700	1.5-17.5	19-47
Scouring	-----	50-110	-----	2,300-5,100	1.36-3.02	-----
Bleaching (range)	8.5-9.6	90-1,700	2,300-14,400	300-14,900	5.0-14.8	38-290
Mercerizing	5.5-9.5	45-65	600-1,900	27,900-36,950	10.5-13.5	185-450
Dyeing:						
Aniline Black	-----	40-55	600-1,200	15,000-23,000	5-10	100-200
Basic	6.0-7.5	100-200	500-800	18,000-36,000	15-50	150-250
Developed Colors	5-10	75-200	2,900-8,200	8,900-25,000	15-20	325-650
Direct	6.5-7.6	220-600	2,200-14,000	1,700-6,400	1.3-11.7	25-250
Naphthol	5-10	15-675	4,500-10,700	2,300-16,800	2-5	200-650
Sulfur	8-10	11-1,800	4,200-14,100	2,900-25,600	2-250	300-1,200
Vats	5-10	125-1,500	1,700-7,400	1,000-20,000	12-30	150-250

TABLE 5-4
CHARACTERISTICS OF COTTON PROCESSING WET WASTES (3)

Process	Significant Pollutant
Desizing	High BOD, neutral pH, high total solids.
Scouring	High BOD, high alkalinity, high total solids, high temperature.
Bleaching	High BOD, alkaline pH, high solids.
Mercerising	Low BOD, high solids, neutral alkaline pH.
Dyeing and Printing	High BOD, high solids, neutral to alkaline pH.

1. pH from 8 to 11
2. colour either grey or that of the predominant dyes used
3. BOD values in the range of 200 to 600 ppm
4. total solids in the range of 1000 to 1600 ppm
5. suspended solids in the range 30 to 50 ppm

The total volume of wastes produced averages between 30,000 gallons to 93,000 gallons per 1000 pounds of cotton fabrics processed.

Depending on the product mix from 100 percent cotton to cotton synthetic blends and the type of technology used, the waste production and characteristics vary. The best method of assessing the waste loads will be by routine, on the spot sampling surveys.

Synthetic Textile Industry

Synthetic textiles include two wide groups of fibers, cellulosic and noncellulosic fibers. The cellulosic fibers include rayon and cellulosic acetate. The noncellulosic fibers used are nylon, polyester, acrylics and synthetic forms, or as a mix blended with cotton or any other natural fibers. The techniques used in processing synthetic fibers differ depending on the type of fiber. Figures 5-2 and 5-3 show flow processes in the manufacture of a 100 percent synthetic fabric and blended fabrics respectively.

Table 5-5 shows the pollutional load of synthetic wet fiber processes.

Winding synthetic fibers is a dry operation and after this stage the fibers are subjected to an aqueous operation known as stock dyeing. The waste liquors produced from the stock dyeing stage consist mainly of various dyes and amounts of 8 to 15 times the weight of the fibers

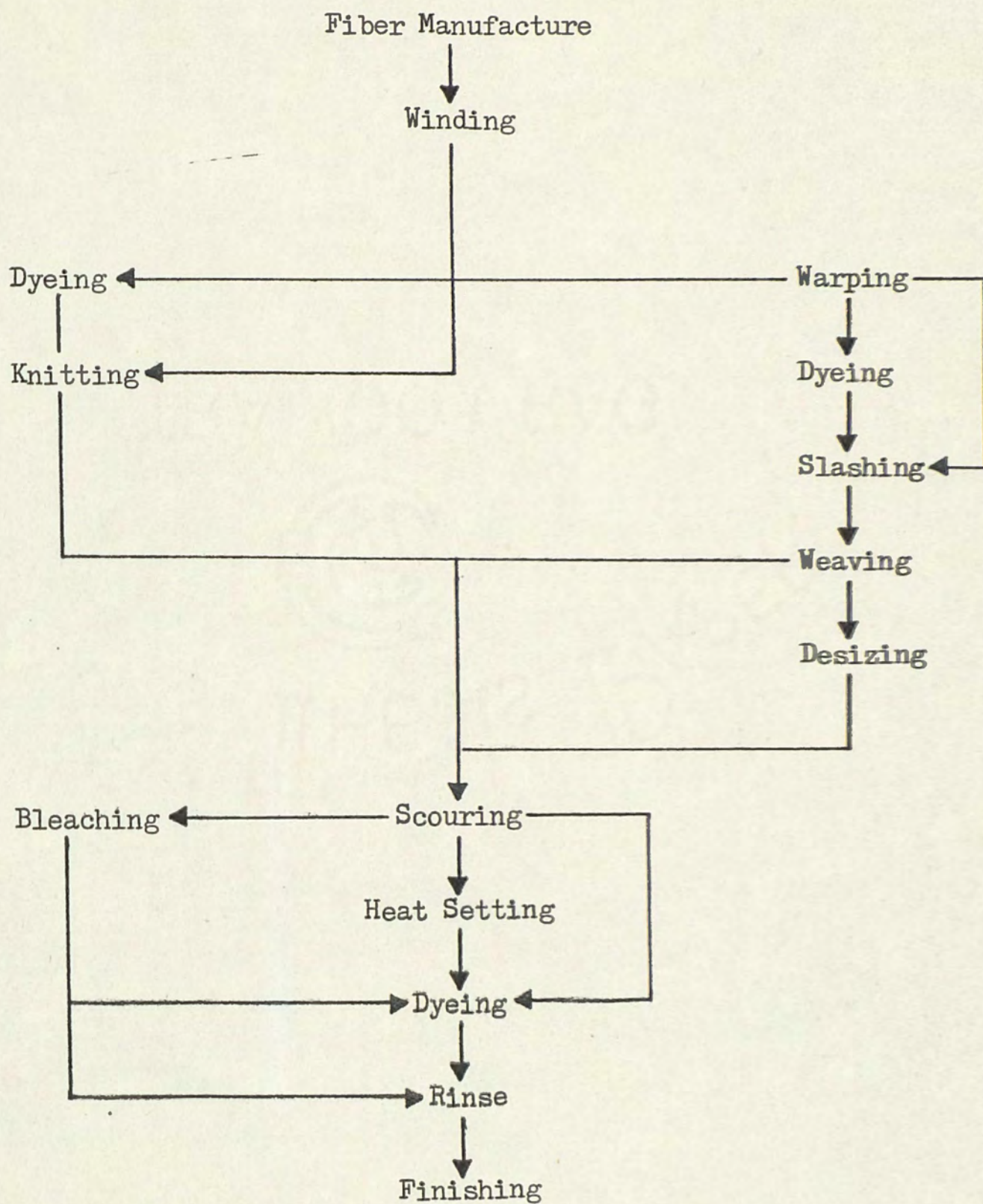


Fig. 5-2. Typical Processing of 100 Percent Synthetic Fabric (3)

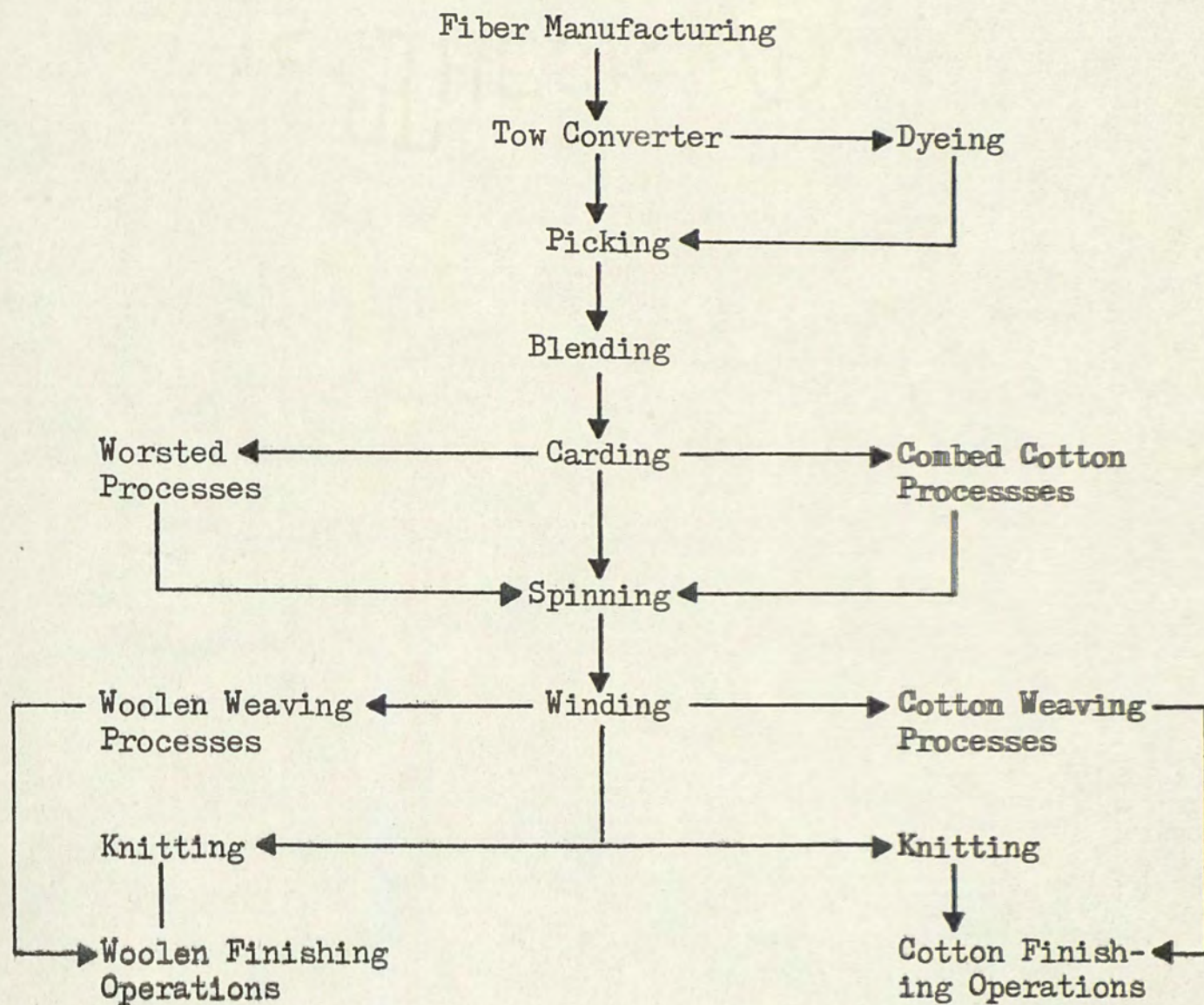


Fig. 5-3. Typical Processing of Blended Fabrics (3)

TABLE 5-5

POLLUTIONAL LOAD OF SYNTHETIC WET FIBER PROCESSES (3)

Process	Fiber	pH	BOD		Total Solids		Suspended Solids lbs/1000 lbs of cloth	Volume in gal per 1000 lbs of cloth
			ppm	lbs/1000 lbs of cloth	ppm	lbs/1000 lbs of cloth		
<u>Scour</u>	Nylon	10.4	1,360	30-40	1882	30-50	20-40	6,000-8,000
	Acrylic/Modacrylic Polyester	9.7	2,190	45-90	1874	12-20	25-50	6,000-8,000
		----	500-800	15-25	----	25-35	5-15	3,000-5,000
<u>Scour & Dye</u>	Rayon Acetate	8.5	2,832	50-70	3334	25-39	0-3	2,000-4,000
		9.3	2,000	40-60	1778	-----	1-20	4,000-6,000
	Nylon	8.4	368	5-20	641	20-34	2-42	2,000-4,000
<u>Dye</u>	Acrylic/Modacrylic Polyester	1.5-3.7	175-2,000	15-800	833-1968	30-200	-----	2,000-4,000
		----	480-27,000		----			
	Rayon	6.8	58	0-3	4890	20-200	2-6	500-1,500
<u>Final Scour</u>	Acrylic/Modacrylic Polyester	7.1	668	10-25	1191	4-12	3-7	8,000-10,000
		----	650	15-25	----	10-50	3-50	2,000-4,000
	Rayon	----	-----	20	----	3-100	3-50	500-1,500
<u>Special Finishing</u>	Acetate	----	-----	40	----	3-100	3-50	3,000-5,000
	Nylon	----	-----	10	----	3-100	3-50	4,000-6,000
	Acrylic/Modacrylic Polyester	----	-----	60	----	3-100	3-50	5,000-7,000
		----	-----	2-80	----	3-100	3-50	1,000-3,000

treated. Physical and chemical aspects of the process vary depending on the fiber used.

Static electricity produced in the fibers during processing is overcome by the application of antistatic oils on the yarns. These act as lubricants and sizing compounds. Common antistatic compounds used contain polyvinyl alcohol, styrene based resins, polyalkene glycols, gelatin, polyacrylic acid and polyvinyl acetate (4). These compounds become a source of water pollution at the scouring stage when they are removed with the washing liquors.

Since the synthetic fibers are free of chemical or other impurities, only light scouring and little or no bleaching is done prior to the dyeing. If synthetics are bleached the process is not normally a source of organic or suspended solids pollution. Chlorine bleaching at this stage produces solid wastes.

Processes Used with Different Types of Synthetic Fibers

Rayon

Scouring and dyeing are usually carried out in a single bath in finishing rayon fibers. Scouring liquid is a mixture of soluble oil and synthetic detergents. Dyes used are the same as the dyes used with the cotton dyeing operations, but the dyeing process is carried out at temperatures in the range of 180°F to 200°F. Retarding agents and lower concentrations of electrolytes are used to effect exhaustion of color (11). The main reason for dyeing and scouring rayon in the same bath is that very little rayon is bleached due

to the degradation of the fiber by the oxidizing agents used in bleaching (11).

A typical rayon and dye bath will contain the antistatic lubricant used for weaving purposes, and the soluble oils, together with the detergents used in scouring (11). The average BOD in this type of a bath was assessed in reference 11 to be 2832 ppm. Of this amount, 50 to 60 percent was contributed by the antistatic compounds, 30 to 40 percent was due to the soluble oil, and 10 to 20 percent was due to the synthetic detergents.

After the scour and dye bath, rayon is subjected to a salt bath to remove residual scouring material and to assure the fastness of the dyes. The bath contains a synthetic detergent and salt solution which is subsequently rinsed from the fabric. Practically, all the BOD of this discharge is due to residual scour and dye bath solution left in the fabric. The waste discharge had an average BOD of 58 ppm and a salt content of 4000 to 12,000 ppm.

In plants utilizing scouring and the dyeing processes for rayon fabrics, the two baths jointly will produce an equalized effluent having a BOD of 1,445 ppm and a salt content of 2,000 to 6,000 ppm. The rate of waste production is assessed to be about 5,000 gallons of water per each 1000 pounds of fabric processed (3).

Acetate

In processing acetate fabrics, a preliminary desizing action, and, if needed, a scour and dye bath or scour and bleach bath for producing coloured or white fabrics, together with two rinsing

operations, is used. The antistatic compounds are solubilized by diastatic or proteolytic enzymes prior to scouring (3). Soap or synthetic detergent is used for scouring, and dyeing is carried out by the use of dispersed dyes, dispersed developed dyes, or acid and naphthol dyes (12). Dispersed dyes have very low solubility and are applied in fine dispersed form. Sulfonated oil, aliphatic ester, and softeners are used with each class of dye at concentrations of about 0.02 pounds per pound of fiber to facilitate dyeing (12). When the fiber swells, the dye solution penetrates into the fiber. The rinses following dyeing remove the swelling agent, and as the fibers unswell, the dye solution gets encased in the fiber (12). In bleaching the fibers mild oxidizing agents like peroxides or chlorine are used. A three percent solution of hydrogen peroxide is the commonly used bleaching agent (3). The wastes from the scour and dye baths average 2,000 ppm and 50 pounds of BOD for each 1,000 pounds of acetate fabric. Scour and dye baths in general contain 40 to 50 percent BOD loading due to antistatic desizing wastes, 30 to 40 percent BOD loading due to the sulfonated oil swelling agent, 10 to 20 percent BOD loading due to the aliphatic ester swelling agent, and negligible contributions of BOD due to the softener used. The composite wastes produced from all the three processes average to 666 ppm of BOD for each 1,000 pounds of fabric processed. The volume of water required per 1,000 pounds of cloth averages to about 9,000 gallons. If bleaching is substituted for dyeing, the BOD of the scouring and bleaching bath approximates to about 750 ppm (3). The equalization of this bath with the discharges from the two rinsings

averages to 250 ppm and 15 to 20 pounds of BOD in 9,000 gallons of wastewater for the processing of 1,000 pounds of cloth.

Nylon

Nylon processing involves scouring, two rinses, dyeing and another rinse. Of interest in the case of nylon is that about 1% of the fiber gets dissolved during the scouring stage. Nylon fibers can be dyed by the use of any class of dyes. In using the nylon with other types of fibers the choice on dyes is made to suit the other fiber (3). A scouring stage uses soap and soda ash. When wasted this scour bath contains the following BOD producing compounds: antistatic compounds, soaps, and fatty esters from the dissolved parts of the fiber. Typical nylon scour bath averages 1,360 ppm and 34 pounds of BOD for each pound of cloth processed. In general the total BOD load is made up of 40 to 50 percent BOD due to antistatic sizing agents, 40 to 50 percent due to soaps, and 10 to 20 percent to fatty esters (3). Sulfonated oils used as dye dispersants in dyeing nylon contribute most of the BOD produced during the dyeing stage, amounting to an average of 660 ppm and 15 pounds of BOD per 1,000 pounds of cloth dyed.

Two rinsing stages between scouring and dyeing processes and the rinse following dyeing are low in BOD. If the wastes from the five processes are combined, scouring and dyeing 1,000 pounds of nylon fabrics results in a waste load averaging 346 ppm and 43.2 pounds of BOD in 15,000 gallons of water (3).

Polyester

In polyester fabric finishing the processes employed are scouring, rinsing, dyeing, and scouring again. In the case of the blended polyester an additional stage of dyeing is used before scouring. A non-ionic detergent is used for scouring (13).

Polyester dyeing is carried out in several different ways. Conventional dyeing with the use of dye carriers at temperatures ranging from room temperatures to boiling temperatures is one method. The second method eliminates dye carriers but high temperatures and pressures are used (13).

A list of dye carriers, BOD loading in ppm and pounds of BOD per 1,000 pounds of cloth are shown in Table 5-6.

Another method of polyester dyeing is thermosol dyeing in which the dyestuff is coated on the fabric and cured on the fabric in an oven. The amount of dye carrier used at conventional temperatures varies from 0.06 to 0.4 pounds of carrier per one pound of fiber dyed.

Polyester scour wastes average from 500 to 800 ppm of BOD. Processing of 1,000 pounds of polyester fabric produces about 15.5 pounds of BOD, 90% of which is contributed by the antistatic compounds used in lubrication and sizing (11). Two rinsing operations of polyester contribute low BOD values. Complete processing of polyester uses an average of 15,000 gallons of water (11).

Acrylics and Monacrylics

The techniques used in processing both these types of fibers

TABLE 5-6

BOD LOADINGS OF POLYESTER DYE CARRIERS

Carrier	BOD in ppm	BOD in lbs/1000 lbs of cloth
Orthophenylphenol	6,000	180
Benzoic Acid	27,000	810
Salicylic Acid	24,000	720
Phenylmethyl Carbinol	19,000	570
Monochlorobenzene	480	14

are the same. Most prevalent methods of dyeing these fibers are with acid dyes using cationic dyeing assistants and with basic dyes using anionic dyeing assistants. The amount of carrier used varies from 0.02 to 0.1 pound of chemical per pound of fiber dyed (11).

The waste from the first scour averages to 2,190 ppm and 660 pounds of BOD per 1,000 pounds of processed fiber. Antistatic compounds and soaps are the constituents of the wastes generated out of which antistatic compounds account for 30 to 50 percent of the BOD. The rinse following the first scour contains the soap and lubricant solution held over from the first scouring process and is usually low in BOD (11).

When using acid dye baths, the dye baths average 175 ppm and 5.3 pounds of BOD per 1,000 pounds of fabric, the total BOD load coming from the carriers. The final scour averages 668 ppm and 20 pounds of BOD for 1,000 pounds of cloth (3). This final scour is accomplished with synthetic detergents and pine oil, which contributes practically all the BOD. In this case, also the subsequent rinse washes are low in BOD. The equalized discharges will have a BOD of 575 ppm and 120.9 pounds in a volume of 25,000 gallons of wastewater per 1,000 pounds of acrylic and monacrylic fabric processed (3).

Treatment of Textile Wastewaters

Textile wastewaters could either be treated together with municipal sewage in municipal sewage treatment plants or could be separately treated by a plant handling textile wastes only. In Srilanka

the major textile complexes are located far from the cities. Hence the tendency will be for independent treatment plants or joint ventures with the small urban councils at which the mills are located. Advantages of combining sewage and textile wastes together are three-fold:

1. Economy of operation due to the reduction of capital outlays and administration costs.
2. Domestic sewage provides sufficient bacteriological nutrients (phosphorous and nitrogen) which are commonly not found in textile wastes.
3. Dilution of textile wastes by domestic sewage weakens the concentration of the former, thus increasing process efficiency, and prevents shock loadings of toxic materials from killing bacteria in the treatment plant.

Decisions regarding the process of treatment will have to start from the collection of data. Due to the various differences at different mills it is advisable to conduct a survey of the mills' wet processes to determine the composition and the volume of the effluents. Especially in the textile industry, the evaluation of major waste producing variables, pounds of chemicals used in each process, pollution contribution of the impurities removed from the fabric, and the process chemicals used, need to be investigated in detail (3).

Total waste load from a mill is the waste load produced by the chemicals used and the natural impurities in the fiber used. BOD loads produced by different chemicals could be assessed by the use of published data (such as data from the American Association of Textile Chemists and Colorists BOD list) available (3).

Sampling the wastes produced from each stage of scouring, desizing, bleaching, dyeing, and finishing operations is needed to

determine the COD, TOC, BOD, pH, acidity or alkalinity values, With these data a mathematical model might be developed to visualize the waste generation process.

The feasibility of minimizing the waste loads from each stage could be evaluated at this point by considering the use of various in plant control techniques. The following methods of inplant control are already practiced in plant control of the U.S. textile industry.

1. Reduction of wastewater volume (4). Counter flow processing and wastewater reuse comes under this category. In the counter flow technique, the fabrics move in a direction opposite to the direction of water flow. The process arrangements are made in such a way that the fabrics carry the least amount of impurities and process chemicals at the last stage of the process. Fresh waters are used at the final stage to remove the small amounts of impurities. The effluent water from this stage is advanced to the preceding unit and by this means the fabrics containing more pollutants are exposed to waters with less pollutants, ultimately reaching a stage where the effluents are less in volume but concentrated with wastes.

2. In using the other method of reducing the volume of wastewater, there is recycling of the same water several times before discharging. Effluents from batch operations like rinsing the fabrics after dyeing can be used to prepare scour, chlorine bleach, and wetting out baths (4). The impurities in particle form are removed in between stages by the use of filters. In using this procedure, due consideration should be given to assure that no chemicals harmful to

the ensuing textile process enters the system. Chemicals like fluorescent brighteners in concentrations as low as 0.5 milligrams per liter, some finishing agents, and salt compounds, could lead to undesirable results during processing.

Reduction of process chemicals leads to lower pollution loads and production economy. Over 90 percent of the pollution load of the textile industry is assessed to be due to the process chemicals. Possibilities of reducing some chemicals usually employed in washing, dyeing, etc., has been investigated and was found to be about 30 percent (11,14).

Recovery and reuse of caustic soda in cotton processing operations (mercerizing and scouring) by the use of dialysis, centrifuging, or evaporation, has been practicable (3).

Under process modification, change of the processes and material flow occurs. Separate operations which could be combined together, such as scouring and dyeing in finishing synthetic fibers, and substitution of baths and rinses into flow processes to conserve water and concentrate the waste load at the bottom of process unit, are examples (3).

Another drastic process modification mentioned in the literature is not to discharge any effluent at all, but to pump the process liquor to a storage tank where it is stored and saved for reuse in the make up of the next similar bath (11). Wastage of heat, together with the thermal pollution, could be avoided by the use of heat exchangers, to transfer the heat available in some effluents (11).

Substitution of different chemicals to reduce BOD has been successful in many cases. Substitutions which are already being made at the textile mills in the US include the use of synthetic warp size (1 to 3 percent BOD) for starch (50 percent BOD), use of ammonium sulfate, chloride, or mineral acids (90 percent BOD), for acetic acid (33 to 62 percent BOD), and the use of low BOD synthetic detergents (0 to 22 percent BOD) for soaps (140 percent BOD). However, the economies of most of these alternative methods with a view towards the use in Srilanka's industry may not be feasible.

Good housekeeping practices are essential in minimizing the wastewater load from any textile mill. Maintenance of close control over the mills' operation to avoid accidental chemical spills from chemical baths, and wastage due to excessive chemical preparation, is important. Elimination of any possibilities of picking up dirt, grease, rust, etc., from the floor and machinery reduces the need for more washing and will require less processing of the fabric.

Synthetic Textile Industrial Wastes

Wastes produced by the synthetic fiber wet processing have a lower pollution potential than those from the cotton processing operations. Polyester and acrylic fiber processing generates most of the pollution load out of synthetic fiber processing operations. Dye carriers of these two fibers are observed to be the main sources of odour, toxicity, and high BOD. Table 5-7 shows the relative BOD load reduction potentials of various process modifications used in the treatment of synthetic fiber wastes. This BOD reduction could

TABLE 5-7

REMOVAL EFFICIENCIES OF TREATMENT METHODS USED
SYNTHETIC FIBER WET PROCESSING WASTES (3)

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

only be achieved by the use of the sequence - scouring to precede or be concurrent with dyeing or bleaching, final scouring (or the salt bath must follow dyeing and special finishing processes if applied) (3). Reuse of processing waste chemicals could be carried out to reduce waste loads as in process control operation.

Dye Wastes

Dyes from textile wastes take various forms and are difficult in handling, mainly due to their colour. Methods of treatment are discussed in detail under the biological methods of treatment. Effectiveness of different physical, chemical, and biological methods in colour removal are shown in Table 5-8.

Treatment of Textile Wastewaters

In treating textile wastewaters from a mill together with sewage, a minimum of seven parts of domestic sewage to 100 parts of textile wastes is necessary to ensure that the proper amounts of nutrients are supplied to the bacteria in the system (15). Pollution parameters of textile wastes could be identified as BOD, COD, suspended solids, colour, chromium, sulfides, temperature, and metallic and nonmetallic concentrations.

A flow diagram of the processes of cotton and synthetic textile waste treatment is shown in Figures 5-4 and 5-5. Preliminary treatment of textile wastes is needed to obtain biologically acceptable conditions by means of segregation, equalization, and neutralization stages.

Segregation of strong alkaline liquors from the rest has been

TABLE 5-8

PEAK COLOUR REMOVAL EFFICIENCIES OF
TREATMENT METHODS USED (3)

Method	Percentage Efficiency
Trickling Filter	84
Activated Sludge	93
Chemical Coagulation of Cotton Dyes	50 to 85
Activated Carbon	90±

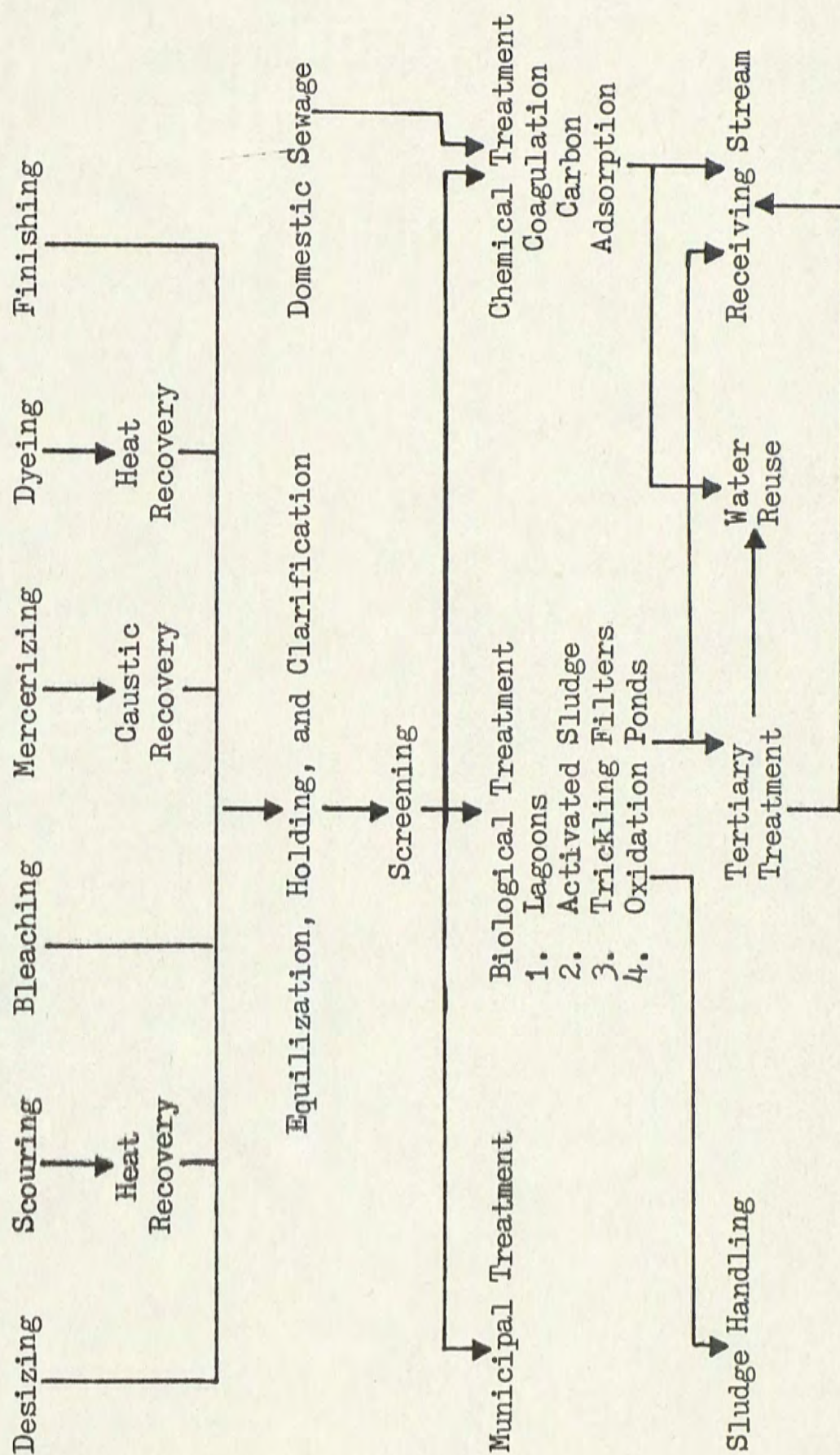


Fig. 5-4. Cotton Waste Processing Flow Chart (3)

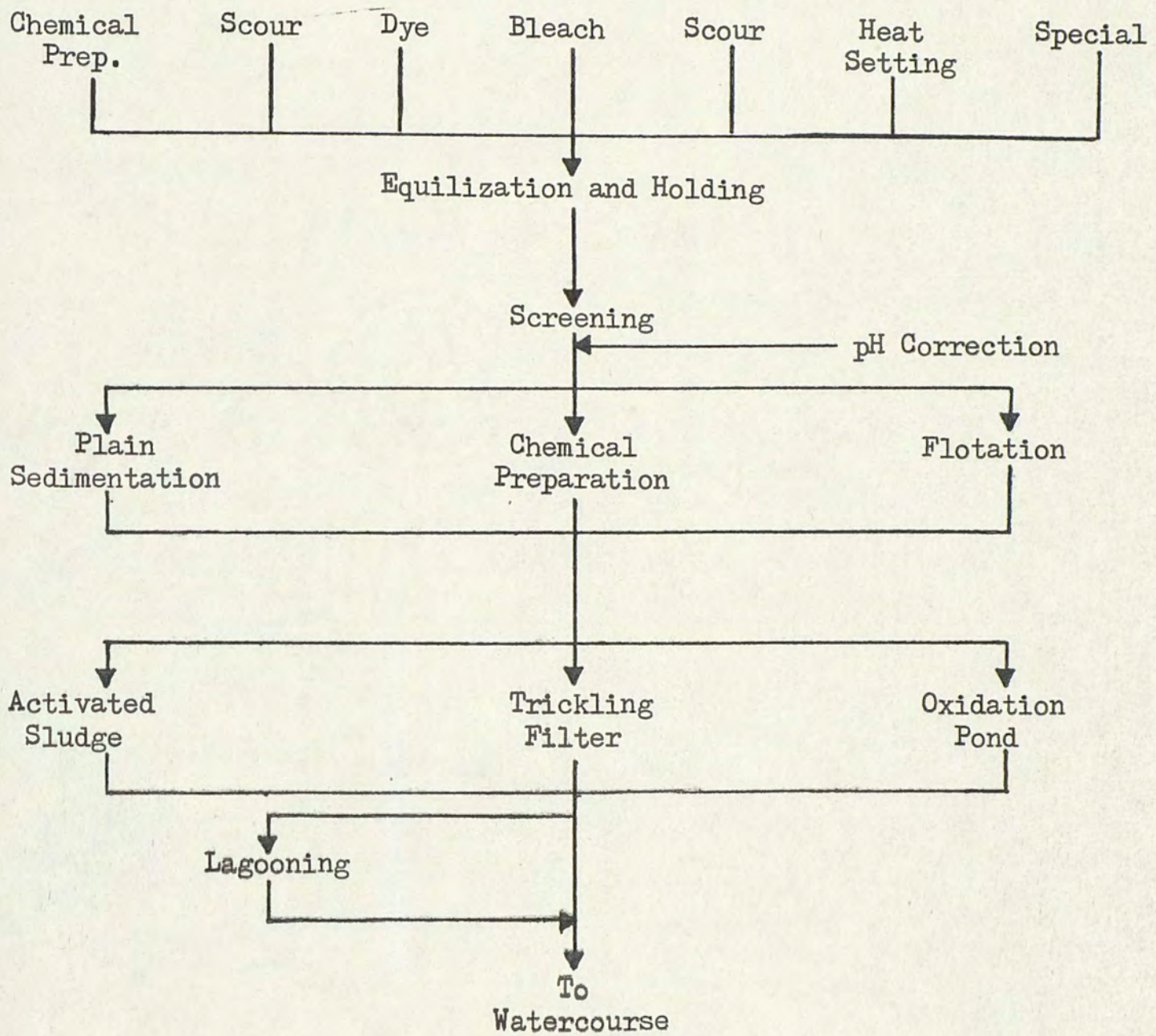


Fig. 5-5. Synthetic Textile Finishing Waste Treatment Flow Chart (3)

found to be more effective in achieving neutralization (3). Equalization is achieved by mixing and storing the effluent in ponds or basins. Use of a single basin to equalize the wastes is disadvantageous, since textile wastes have density variations caused by variations of temperature and composition of effluents (3). Liquid layers of low density and high temperature rise to the surface and pass through a gravity layer quicker. The high density, low temperature, layers settle down to the bottom. Use of three separate basins to receive, mix, and supply the effluents to the next stage is recommended. High pH values are preferred at this stage to overcome septic conditions.

Mixed liquor generated from cotton textile mills are generally alkaline, black in colour, and contain pieces of lint, fiber, and other suspended solids (3).

Secondary treatment of textile wastes involves oxidation of organic matter by aeration, chemical, or biological means, or a combination of each. Three methods of biological treatment are commonly used in textile wastes; namely, anaerobic decomposition, mechanically induced aeration, and natural aeration (3).

Anaerobic Processes

Tropical climatic conditions are helpful in the anaerobic treatment of textile wastes due to their highly concentrated nature and the presence of hot wastewaters. Anaerobic or facultative microorganisms breakdown the wastes into intermediates such as organic (4) acids and alcohols. Methane bacteria convert the intermediates to

carbon dioxide and methane. Sulfur compounds present are converted to hydrogen sulfide gas.

Anaerobic lagoons are feasible in Srilanka due to the presence of hard (alluvial) clayey soils and should be economical to construct and operate. These have the added advantage of being susceptible to shock waste loadings, but the main disadvantage is odour problems which could be avoided by good management. Usually anaerobic lagoons are used as the first stage in secondary treatment and followed by aerobic lagoons. Anaerobic lagoons usually have two relatively deep (10 to 17 feet), low surface area, ponds with typical waste loadings of 15 to 20 pounds of BOD per 1,000 cu. ft. and a detention time of several days. Aerobic lagoons are 3 to 8 ft. deep with BOD loadings of 20 to 50 pounds per acre and detention times varying from several days to six or seven months. Placing a small (4) mechanically aerated lagoon between anaerobic lagoons is becoming popular. Aerated lagoons are 8 to 15 ft. deep, are equipped with mechanical aerators or diffused air systems, and have detention times in the range of two to ten days.

Screening of wastewater flow with fine meshed vibrating screens or Swedish process (where a current of liquid which flows away from the filtering screen catches up the solid matter on the screen and then is fractionated and returned to the system) is used in separating the larger sized suspended solids (4).

pH adjustment of the mix is made by using sulfuric acid or carbon dioxide. Addition of carbon dioxide is carried out either by aerobic biological oxidation or by use of flue gases. In using

flue gases the alkaline wastes are exposed to a counter current flow of carbon dioxide in a steel tower (16).

Coagulation of liquors by the use of aluminum and iron salts before an initial sedimentation stage is sometimes used. In the case of treating wastes containing heavy concentrations of dyes, the Niers method is used (continuous coagulation by ferrous sulfate formed in situ from iron turnings added to the wastes saturated with flue gases) (16). This technique has been observed to yield very good results. This method produces less sludge and is highly effective in the removal of any sulfide content (16).

Chemical pretreatment, coagulation, and segregation are to be performed before secondary biological treatment, if the wastes contain toxic materials. Reductions of 85 percent BOD and 85 percent suspended solids are being achieved by anaerobic lagoons, while aerated lagoons achieve only 40 to 60 percent BOD reductions with little suspended solids reductions. Studies of anaerobic lagoons (4) indicate that loads of 500 to 3,000 lbs. of BOD per acre per day could be applied with BOD reductions of 39 to 45 percent and, when followed by aerobic ponds, a total reduction of 80 to 99 percent could be obtained without odour nuisance.

Anaerobic contact systems use more equipment than anaerobic (4) lagoons. The equipment consists of equalization tanks, digesters with mixing equipment, air or vacuum stripping units, and sedimentation tanks. Overall reductions of 90 to 97 percent in BOD and suspended solids are achieved. In this method equalized flow of wastewater is introduced into a mixed digester where anaerobic de-

composition takes place at 33 to 35 degrees Celcius. BOD loadings to the digester are between 0.15 to 0.20 pounds per cu. ft. Detention times lie between 3 and 12 hours. After gas stripping the digester effluent is clarified and sludge is recycled at the rate of about $1/3$ of the raw waste volume influent rate. Sludge, at the rate of about 2 percent of the raw waste volume, is removed from the system. The advantages of the system are that high organic waste load reduction occurs in a relatively short time and methane gas is produced which would be used as a source of energy.

Activated sludge treatment with its varied forms is used as an attractive treatment process in the textile waste stabilization. General experience in using the method (3) suggests that high levels of efficiency are possible if biological solid separation problems are avoided, if the dissolved oxygen concentration remains above zero throughout aeration basin, and if management minimizes very strong concentrated waste releases. Sufficient amounts of nitrogen also are needed to maintain the critical nitrogen-BOD ratio at 3 to 4 pounds of nitrogen per 1,000 pounds of BOD removed.

The most popular biological system (4) for treating textile wastes is the activated sludge extended aeration method. However, as reported in reference 3 when using percolating filters or a long aeration with activated sludge, it is necessary to recirculate the wastewaters, mainly due to the presence of cotton boiling liquors, whose treatment is fairly difficult. They considerably reduce the sorptive capacity of biological slimes on the filters and the activated sludge flocs. These difficulties are overcome by using

a contact stabilization process. In pilot plant experiments carried out by Jones, Alspaugh, and Stokes (17) on mixtures of textile and domestic wastes using an aeration tank in which the wwastes were fed two thirds of the way along the front, where the return sludge was stabilized before coming into contact again, an aeration time of 2 to 4 hours was found to be the best for stabilization of return sludge. Optimum contact time of the wastes with the activated sludge was 47 to 75 minutes. Final results obtained revealed reductions of 86 to 90 percent BOD, 82 to 98 percent suspended solids, and 61 to 70 percent colouration. When the mixture contained only 7 to 10 percent of domestic sewage a BOD reduction of 85 to 95 percent was obtained but the required aeration time was very long, a minimum of 72 hours.

With trickling filters at a recirculation ratio of 1.5 after neutralization (16), and alum addition for coagulation and sedimentation at pH values in the region 6 to 8, BOD reduction of 90 percent was observed. The same plant with no primary treatment and influents at pH values of 10 to 11, showed BOD reductions of only 60 to 70 percent. At times, additional nutrients in the form of dibasic ammonium phosphate have been provided. Another laboratory research report (1) indicated that at a high loading of 2.73 pounds of BOD per cubic yard of stone, with a relatively high pH of 10.5, a 58 percent reduction of BOD and 42.5 percent colour removal occurred. These illustrate that even if the neutralization is not carried out, the trickling filter units can operate, though the efficiency of operation is low.

Most of the design criteria connected with the biological treatment of sewage are applicable in the treatment of textile and sewage mixes.

CHAPTER VI

PULP AND PAPER INDUSTRY - WASTES AND WASTEWATER TREATMENT

Pulp and Paper Industry and the Methodologies

Manufacturing of pulp and paper in Srilanka dates back to early 1950's. However, a realistic industrial development of the industry only started in 1960's with new developments of the Valachchenai mill coming into operation. Main raw materials used by the industry are imported pulp, illuk grass, paddy straw, kenaf, and other woody materials. Although the pulp production is not presently carried out, with the proposed extensions of the new mills under construction at Embilipitiya and Rajangana, pulp production is expected to be undertaken.

A general description of the industry is given at the early part of this chapter in order to furnish sufficient knowhow on the process activity.

Manufacture of paper can be divided into two main phases called pulping the wood and making the final products. Raw materials generally used in the pulping stage are wood, cotton, or liner rag, straw, hemp, esparte, flax, jute, or waste paper.

Pulping reduces the raw materials into refined fibers. Several methods of pulping are available using chemical or mechanical methods or a combination of the two. Kraft pulping and neutral sulfite semi-

chemical processes are the main types of processes used (5).

Kraft Pulping (Sulfate Pulp) (15.16)

This is an alkaline chemical process where unbarked logs are turned into pulp. A flow diagram of the process used is shown in Figure 6-1. Bark is removed from unbarked logs in a wet or dry process and the logs are then chipped for conveyance to the digester. The digester is a large steel pressure vessel heated with steam to about 150°C . Here the chips are cooked, either as a batch or continuous operation, to dissolve lignin and separate cellulose fiber. The cooking liquor is a mixture of caustic soda and sodium sulfite (in 4:1 ratio). The weight of chemicals used is 20 to 25% of that of the wood.

After the digestion stage, the pulp is ejected into a blow tank from which, along with the spent cooking liquor, it is then transferred on to a "brown stock" chest or tank. Subsequently, it passes to a vacuum drum washer or a continuous diffuser, where the spent cooking liquor is separated by counter current washing. In older practice, the pulp is blown directly to the diffuser through the digester.

Due to the cost of chemicals and heat energy utilized by the process, a high degree of liquor separation with as little dilution as possible is essential.

Separation of fiber is carried out by three to four stages of washing known as brown stock washing, sometimes employing blow tank condensate. In modern mills vacuum washers and diffusers are used

for this stage. In many craft mills the pulp is screened and/or refined prior to brown stock washing to economize the washing stage and to improve the quality of fiber used.

After the washing stage diluted pulp is again screened to remove knots, uncooked chips, pitch particles, etc., and is used for the production of unbleached paper and paper board, or it is thickened to a high consistency for further processing or storage.

Weak black liquor produced by the washing operation contains about 10 to 16 percent solids. In addition to the inorganic cooking chemicals, it contains organic wood constituents separated in the pulping process. The weak black liquor is concentrated to about 45-50 percent solids in long tube multiple effect evaporators and the resulting viscous mass is called "strong black liquor." This is concentrated to obtain 60 to 65 percent solids in the recovery furnace contact evaporator, or in a concentrator. Cooking chemicals used up in pulping and washing are replaced with a make up chemical sodium sulfate or a residue with a high content of sodium sulfate. Acid sludge from oil treatment, raffinate from byproduct production, NSSC waste liquors and ash from incineration of NSSC liquor, are examples of such residues. Salts captured from the recovery furnace stack gases are also reintroduced into the system. Sulfur and caustic soda are sometimes used to adjust the sulfidity.

The strong black liquor produced from this stage is burned and the heat is recovered in an especially designed boiler. At this stage, the organic sodium compounds are converted to sodium carbonate and sulfates to sulfides. The molten smelt of salt obtained,

dissolved in water (green liquor), is clarified and causticized with lime to get caustic soda. This liquor containing sodium sulfide and sodium hydroxide (known as white liquor) after settling and filtration is reused with weak cooking black liquor for pulping.

Settled lime mud obtained from the settling stage is concentrated, dehydrated, and burned to produce quick lime for reuse. The kraft chemical recovery system is shown in Figure 6-2.

NSSC Process (Sulfite Process)

Main features of this pulping process are impregnation of hard wood chips with cooking liquors at high temperature and mechanical defiberizing. The flow diagram for the NSSC pulping process (sodium based) is shown in Figure 6-3. The ammonia based NSSC pulping process uses ammonia in place of soda ash. Some mills buy cooking chemicals while others produce the sodium sulfite requirement by burning sulfur and absorbing the gases in a solution of soda ash or ammonia. Some modern mills employ continuous digesters, although a large number of mills use batch digesters. Softened chips from the digesters are compressed in one or more stages by screw pressing. This facilitates the maximum recovery of spent liquor and partial washing of the pulp with minimum dilution. Either from this stage or directly from the digester the softened chips are sent to a disk mill for fiberizing. At this stage the chips undergo vacuum or pressure washing, screening, and centrifugal cleaning. Digester relief blow gases are condensed, and the condensate in some cases is used in pulpwashing.

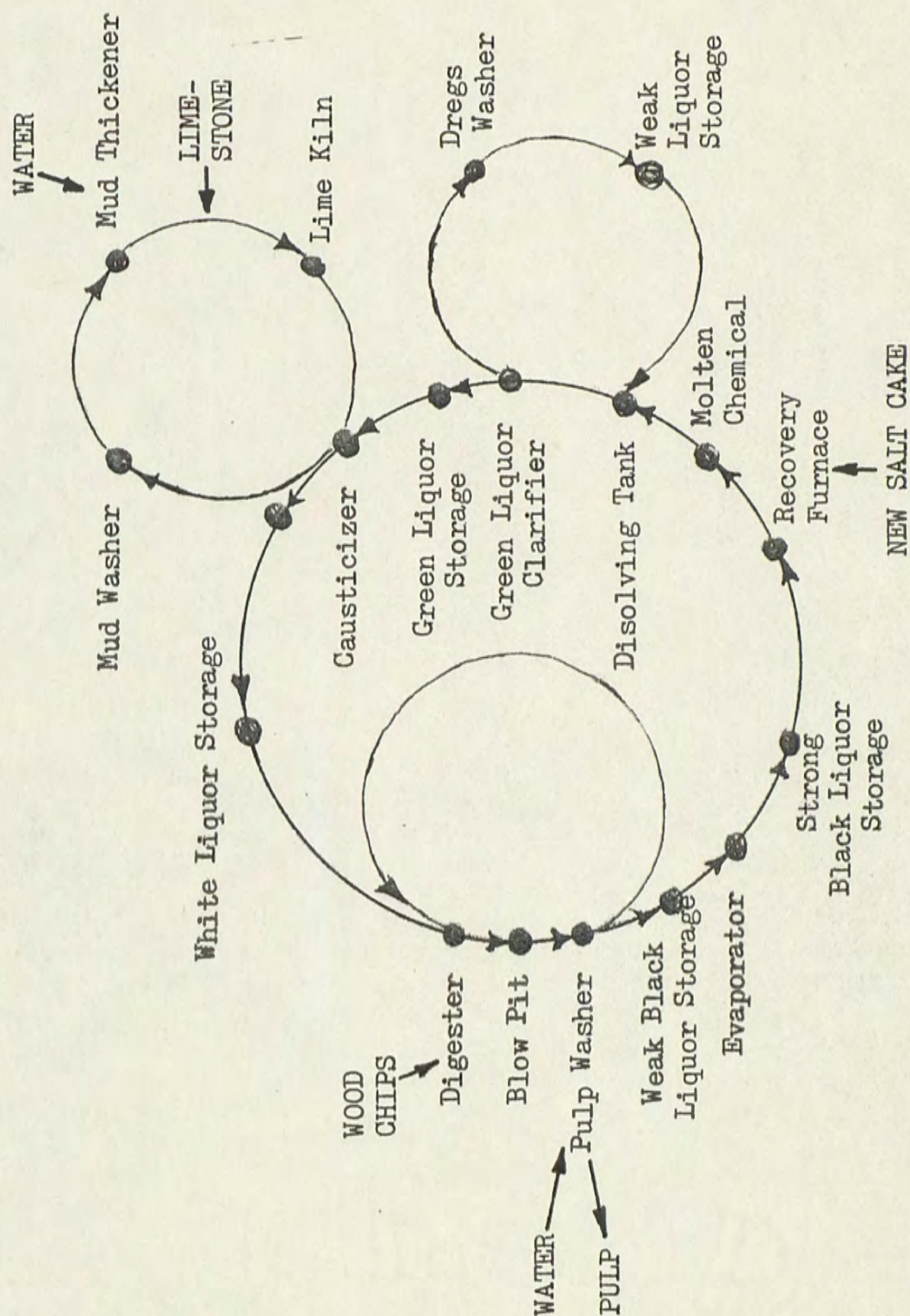


Fig. 6-2. Kraft Pulping Chemical Recovery

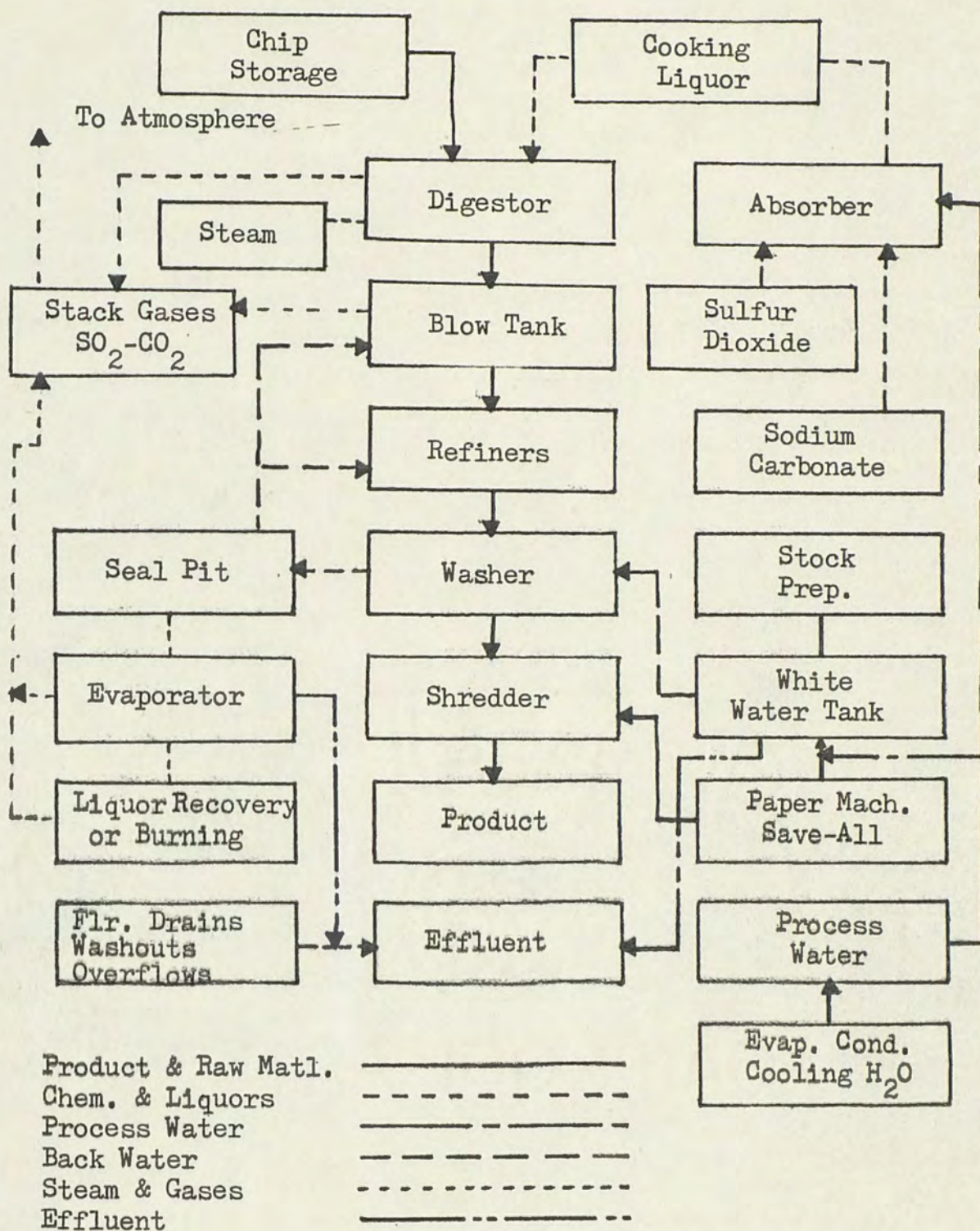


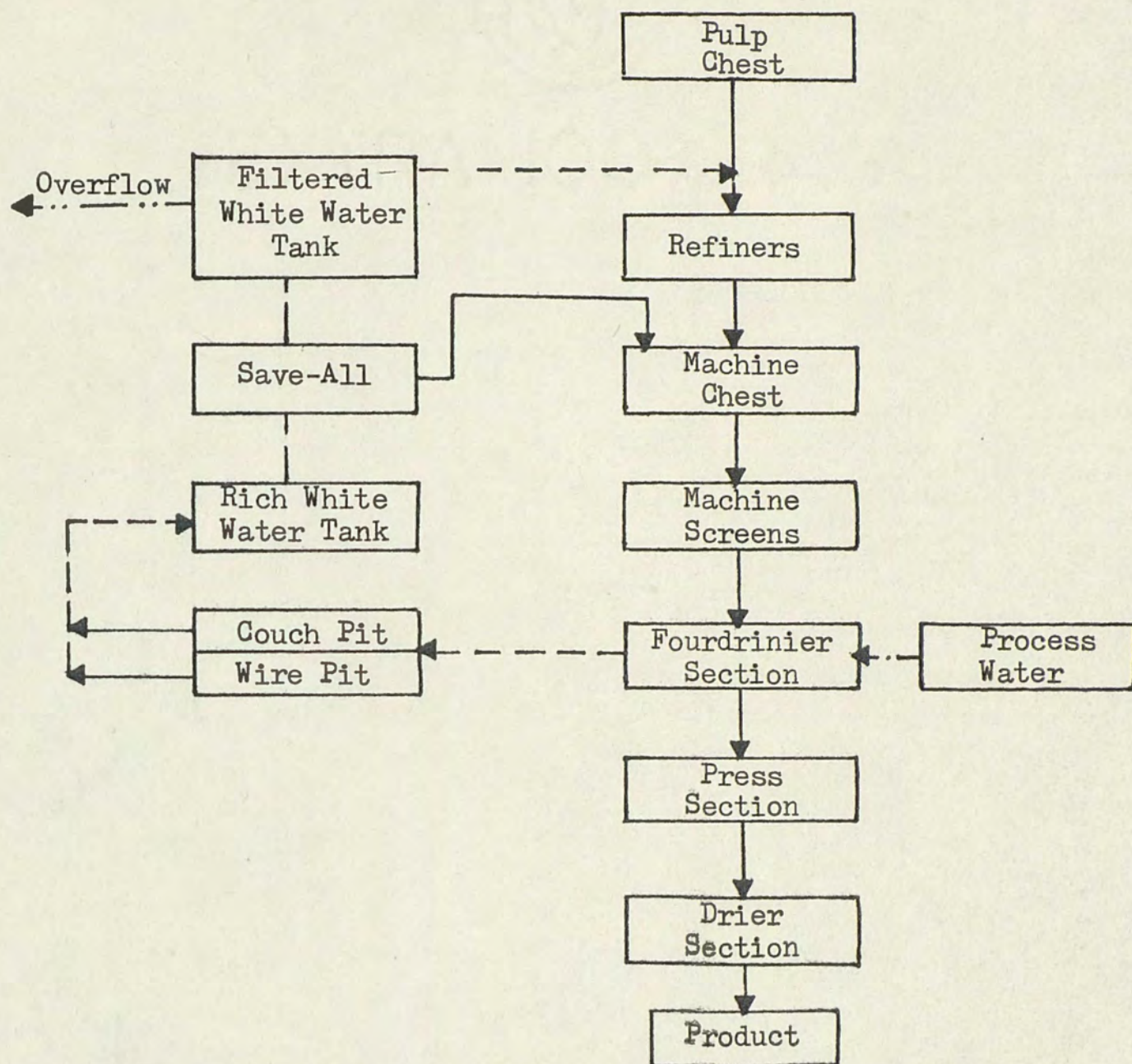
Fig. 6-3. Neutral Sulfite Semi-Chemical Pulp Process Diagram (5)

Due to the difficulties encountered in chemical recovery, the common practice is to concentrate the liquor by evaporation, to burn or reuse the spent liquor with Kraft pulp manufacturing effluents. Purification is by the Kraft waste recovery system for reuse in the Kraft pulping process. The Kraft-NSSC cross-recovery method results in a profitable combination.

Paper Production

The paper making process involves first, a selection of the appropriate mixture of pulps (wood, rags, flax, jute, straw, old newspapers, etc.). The pulp mixture at first is disintegrated, washed and then mixed in a beater. Addition of various fillers like adhesives, alum, starch, and kaolin, together with dyes, is carried out at this stage, to improve the quality of the final product. Mixed pulp with the correct composition, is then deposited as a layer of fine fiber on a wire screen. The screen permits the water to drain away. The layer formed is removed, pressed, and dried to produce quality paper. The machines used by the industry are either of the cylindrical or of the Fourdrinier type.

The water which drains through the paper machines is known as white water and contains suspended fiber, pulp, fines, and additives used. The white water is reused, first in the paper production stage and then in the pulping stage. A flow diagram of processes used in Fourdrinier paper machines is shown in Figure 6-4.



Product & Raw Matl.
 Process Water
 Refuse Water
 Effluent

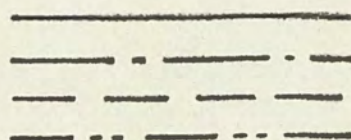


Fig. 6-4. Fourdrinier Paper Machine Process Diagram (5)

Paper Board from Waste Paper (18)

A production flow process of paper board manufacture is in Figure 6-5. Conversion of waste paper to secondary fiber board uses a mix of chemicals (similar to paper manufacture) and steam in a pulper with the waste paper. In the pulper the paper follows water circulating in a large open vat and is repeatedly decomposed by mechanical and chemical action. The pulper operation may be in the form of a batch or continuous. A junker is used to separate the extraneous solid matter out of broth by centrifuging. The stock is then passed to a centrifugal cleaner and finally to a thickener and pressure screens. The final pulp enters the paper machines and the techniques are similar to the paper manufacture.

Waste Characteristics and Inplant Control Methods (5)

Raw waste water characteristics of the industry are shown in Table 6-1, with reference to a survey conducted for the EPA in 1974.

NSSC Sulfite Liquor Process

The highest load of waste liquors from the industry together with high BOD values in the region of 3,000 to 40,000 mg/l are produced in this method. The composition of the wastes is shown in Table 6-2. Sulfite liquor separated from the filters(5), presses and diffusers, or in blow pass stages, is considered to be one of the most concentrated industrial wastes generated in bulk. The non-cellulosic part of the wood which is removed in the pulping process amounts to about 50% of the mass of wood. This is known in the industry as "in-crustating substances." The amount of waste generated varies from

TABLE 6-1

RAW WASTE CHARACTERISTICS OF PULP AND PAPER INDUSTRY,
PER TON OF PRODUCT (5)

Process	Flow (1000 gal/ton)	BOD (lbs/ton)	TSS (lbs/ton)
Unbleached Kraft	9.4 - 20.5	24 - 56	38 - 56
NSSC Ammonia	8.3	67.0	34.0
NSSC Sodium	4.8 - 25.6	22 - 90	8 - 46
Kraft NSSC	10.4 - 17.8	28 - 54	24.9 - 57
Paperboard Waste Paper	1.2 - 16.4	8 - 40	5.6 - 162
Bleached Sulfate and Paper	39 - 54	30 - 220	50 - 200
Unbleached Sulfate and Paper	27		50
Bleached Sulfite and Paper	40 - 70	235 - 430	40 - 100

TABLE 6-2

COMPOSITION OF TYPICAL SODIUM BASED
NSSC (SULFITE) WASTES (3,16)

Component	Content in gm/l		
Total Solids	109.5	to	138.5
Mineral Acids	15.72	to	26.73
Volatile Organic Acids (total)	4.46	to	6.41
Formic Acid	0.63	to	1.19
Acetic Acid	4.28	to	5.22
Calcium Oxide	6.47	to	9.47
Sulphur (total)	10.29	to	11.68
Sulphites, SO_3^-	1.304	to	2.352
Free Sulphurous Acid	1.39	to	5.42
Semi-Combined Sulphurous Acid	4.98	to	6.10
Organic Sulfur Compounds (Sulphonics)	9.47	to	14.18
Permanganate Value (O_2)	102.0	to	1110.0
Methyl Alcohol	0.157	to	0.230
Acetone	0.099	to	0.134
Furfural	0.228	to	0.285
Lignin	56.4	to	69.6
Carbohydrates (total)	20.10	to	20.64
Pentoses	2.55	to	3.37
Hexoses	17.1	to	17.9
Usual BOD_5 Range	3000 to 40,000 mg/l of O_2		
pH	About 3.0		
Colour	Brown		

9,400 to 20,500 gallons per ton of pulp produced (5). The wastes from the washing and dewatering of pulp yield dilute liquors with properties similar to cooking liquors. The wood yard liquors are the least noxious.

Pulp washing processing stage wastes contain cellulosic fibers. If the pulp is bleached, the bleaching wastes have chlorinated non-bleached pulp products, hemicellulose hydrolysed to monosachcharides, resins, and other substances extracted from the fiber, together with some free chlorine.

The effluents as a whole may contain, in addition, the inorganic compounds from the washers of sulfur dioxide produced at the site. These carry pyrite dust and synder containing sulphuric and sulphurous acids, and iron and lead salts with traces of arsenic (5).

If bleaching is carried out with bleaching powder, the waste flow will include calcium hypochlorite, calcium hydroxide, free chlorine, and calcium hydrosulfite (which partially decomposes into calcium sulfite and calcium sulfate) (5).

Recycling these waste liquors in a Kraft paper process is the best practicable method of using these wastewaters.

Sulphate Pulp Process (Kraft)

The mixed wastes from this process contain dissolved organic compounds such as sulfates, sulfides, thioethers and mercaptans (16). The composition of sulphate wastes in general are given in Table 6-3.

Effluents from the manufacture of bleached pulp from this stage contain additional chemicals similar to the same NSSC process.

TABLE 6-3
CHARACTERISTICS OF KRAFT MILL WASTES (16)

Characteristic	Range of Concentration
pH	7.6 to 9.5
Total Alkalinity, ppm	100 to 300
Phenolphthalein Alkalinity, ppm	0 to 50
Total Solids, ppm	800 to 2,000
Volatile Solids, %	60 to 75
Total Suspended Solids, ppm	76 to 300
Volatile Suspended Solids, ppm	80 to 90
Color, units	35 to 100
BOD ₅ Day, ppm	100 to 350

Paper and Paper Board Production

The quality of the effluent from these mills varies in accordance with the quality of paper produced and the type of mill.

Table 6-4 shows the waste loads and pollution parameters of paper mill effluents of various categories.

Internal Control of Effluents from Bleached and Unbleached Kraft Processes

Methods for reduction of pollutant discharges by inprocess control include effective pulp washing, chemical and fiber recovery, treatment and reuse of selected waste streams, collection of spills and prevention of accidental discharges (5). The internal measures in turn help the recovery of chemicals and heat.

In the wet barking process the effluents, after screening and clarification under a design rise rate of 1000 to 1200 gallons/sq. ft./day and a retention time of about two hours (5), could be reused. Raw waste load generated after cooking and re cooking stages and by pulp screening should not be allowed to enter the wastewater flow. Inert materials originating in the Kraft recovery process, inert grits from the lime slaking, and white or green liquors from clarification stages, are to be disposed out from the site as solid wastes for land disposal. Kraft mill condensate containing heavy BOD could be reused.

One third to one fourth of the industries' BOD and suspended solids in the raw wastewater are due to spills, overflows, and wash-ups which occur during production. Good management and housekeeping are highly effective in controlling the pollution loads. However,

TABLE 6-4

WASTE LOADS AND WASTEWATER CHARACTERISTICS OF DIFFERENT
PAPER PRODUCTION PROCESSES (1)

Process	Waste Load in lbs/ton of Product				pH	Wastewater Quantity in gals/ton
	Suspended Solids	Dissolved Solids	Total Solids	BOD		
General Related Products	10-166	21-425	31-591	3-80	4.3-6.9	5,700-100,000
News Print	20-60			10-12		
Uncoated Paper	30	66	116	16		8,000- 28,000
Fine Paper	47-100	80	153	15-40		9,000- 40,000
Coarse Paper	10-30			10-25		2,000- 29,000
Special Industrial Paper	200-400			140-170		20,000-100,000
Sanitary and Tissue Paper	50-100	150	200	15-30		8,000- 37,000

due to the probability of shock load generation from mills, the storage lagoons located prior to the biological treatment processes are provided with sufficient over capacity. Slime growth, scale build up, buildup of dissolved solids, and corrosion are a few problems caused by the recycling of wastewaters of the industry. Mixing of the recycled water with more fresh water provides some control of these effects.

Recovery of fibrous and suspended solids from paper machine wastewaters uses the same all techniques. Save alls are of three types - older drum type, disc type and dissolved air flotation type. The effluents from the save alls could be used in vacuum pump seals, machine showers, stock cleaner elutriation, cooling waters, pulp washing, washups, consistency regulation dilution, barometric evaporator condensers, and repulping of fiber (5).

Internal Control of Effluents from NSSC Process

The technology and the methods used in the inplant control from this process are similar to those in the Kraft process, except for the additional care needed in handling the different chemicals used.

By-Product Recovery

Although the wastes generated from the industry could be reused in the production of a vivid range of products, a few of them are economical enough for production.

Sulfite waste liquors are used in the production of ethyl alcohol, and yeasts (Torula and Fodder types) (16). The following com-

pounds may also be produced from sulphite waste liquors by fermentation: acetone and butanol, butylene glycol, glycerol, lactic acid, butyric acid, and citric acid (3,16). Lignosulphonic compounds are converted into synthetic tanning agents of the Rotanine type, activated carbon, oxalic acid, vannillin, and nitrophenols. The production of these lower molecular compounds from high molecular lignins is carried out in Germany by the use of hydrogen peroxide and other peroxides in an acid medium. Sulphite liquors also can serve as material for the manufacture of dyes, plastics, disinfectants, foaming agents, ion exchangers (ligninite), dispersing agents, emulsifiers, and wood impregnating agents. Colloidal properties of these wastes are utilized (after concentration) as a binder in the production of briquettes for the nonferrous metal industry.

Pulp and Wastewater Treatment Technology

The pulp and paper wastes are nutrient deficient. The methods used to treat the wastes differ from process to process and mill to mill. The major pollution parameters are observed to be suspended solids, BOD, COD, colour, acidity, chemicals, and heat.

A generalized approach to wastewater treatment processing is difficult. The treatment methods include (a) lagooning for storage, settling, equalization, and, in some cases, for bio-degradation of organic matter, (b) sedimentation and flotation to remove suspended matter, (c) chemical precipitation to remove colour, (d) activated sludge method and other biological treatment methods, (e) activated

carbon for removal of colour, and (f) polishing ponds as final tertiary polishing stages.

Screening of the waste flow passing into the treatment plant is essential to separate the suspended solids particles and other debris. The nutrient deficiency and the corrosiveness of the wastes are overcome by treating a mixture of sewage and industrial wastes. Under research carried out (19) on the joint treatment of sewage together with pulp and paper effluents, the contact stabilization and Kraus process were found to be highly satisfactory. In deciding on the methods of treatment the amount of land available and the climatic data are critical. Figure 6-6 shows a set of comparison curves for evaluating the approximate land requirement for treatment of pulp and paper wastewaters using different techniques, with respect to the wastewater flow in MGD.

The most widely used method of sedimentation of pulp and paper (5) mill waste is the mechanically cleaned quiescent sedimentation basin. These large circular (concrete) tanks are equipped with rotating sludge scraper mechanisms mounted in the center. Effluent usually enters the tank through a well located on a center pier.

Settled sludge is raked to the center sump or a concentric hopper and is conveyed for further concentration or disposal by solids handling pumps. Floating material is collected by a surface skimmer attached to the rotating mechanism and is discharged to the hopper.

At Kraft (NSSC) mills, the clarifier diameters vary in the range from 30 to 350 ft. The overflow rates used vary from 392 to 2,030 gallons per sq. ft. per day. But a majority of the mills

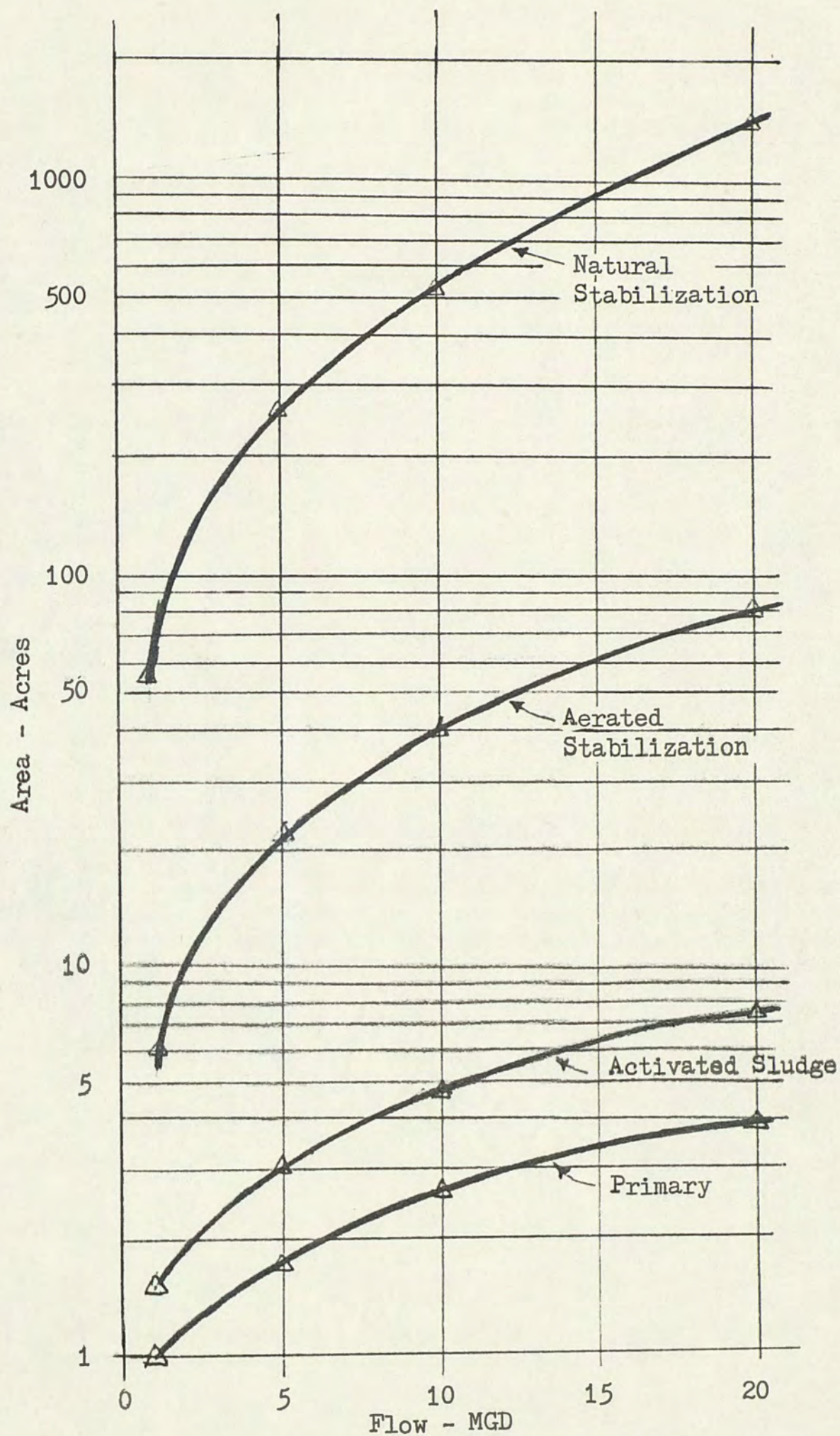


Fig. 6-6. Land Required for Wastewater Treatment

in the US have primary clarifiers with over flow rates ranging from 200 to 700 gallons per sq. ft. per day. Properly designed clarifiers remove 95% of the settleable suspended solids from most of the pulp and paper wastes.

BOD reduction is generally accomplished by the use of very large storage oxidation basins, aerated stabilization basins, or activated sludge processes. The aerated stabilization basin is the most widely used method in Kraft mill effluent treatment. This method is used to treat effluents from many mills together with the stabilization basins. The activated sludge method is not used by the bleached Kraft mills presently. Since the storage oxidation basins are low rate processes, land area requirements are fairly high. Note this method is adaptable to semitropical or tropical climates. 90% BOD removal efficiency for an 82 day detention time stabilization basin, treating Kraft effluents, has been reported. Design loading rates of 50 lbs. of BOD per acre per day for natural oxidation basins, achieving 85 to 90 percent BOD removal in warm climates, have been reported (5).

Aerated stabilization basins require much less land than natural stabilization methods. Because of the long reaction period these require less nutrient addition than activated sludge processes. Detention times in the aerated stabilization basins normally range from 5 to 15 days, averaging about 10 days (5).

Due to the relatively long aeration times the build up of sludge is less than with the high rate processes (5). Typical rates are 0.1 to 0.2 lbs. of sludge per lb. of BOD removed. A prior clarifi-

cation stage voids unnecessarily heavy sludge buildup in the basins. Sludge buildup impedes the efficiency of the process which could be regained by dredging the sludge out. Nutrient deficiency is overcome at some mills by adding deficient components nitrogen and phosphorous. Reported optimum ratios of BOD to nitrogen are 50:1 with four days aeration, and 100:1 with 10-15 days aeration (5). Oxygenation efficiencies under actual operating conditions range from 1 to 2.5 lbs. of oxygen per horsepower per hour depending on the type of aerator used and the aeration power per aeration unit in the lagoon. 1.1 to 1.3 lbs. of oxygen per lb. of BOD is required to maintain a dissolved oxygen level of 0.5 mg/l in the basin (5).

Figure 6-7 shows a flow diagram of a process for treating pulp and paper mill effluents without the use of aeration basins.

A research project conducted to determine the technical and economic feasibility of jointly treating sewage and the weak effluents from pulp and paper mills in the Green Bay, Wisconsin, sewage district led to the following conclusions (19).

A combination of weak effluents from pulping effluents of NSSC processes and de-inking processes could be successfully treated jointly with municipal sewage in an activated sludge plant. Of the four activated sludge processes studied (conventional, step aeration, contact stabilization, and Kraus) the contact stabilization process proved to be the most successful in treating the particular combination of wastes. Filamentous bacterial growth in the mixed liquor was successfully controlled by the continuous addition of 5-10 mg/l of chlorine to the returned activated sludge. Low dissolved oxygen

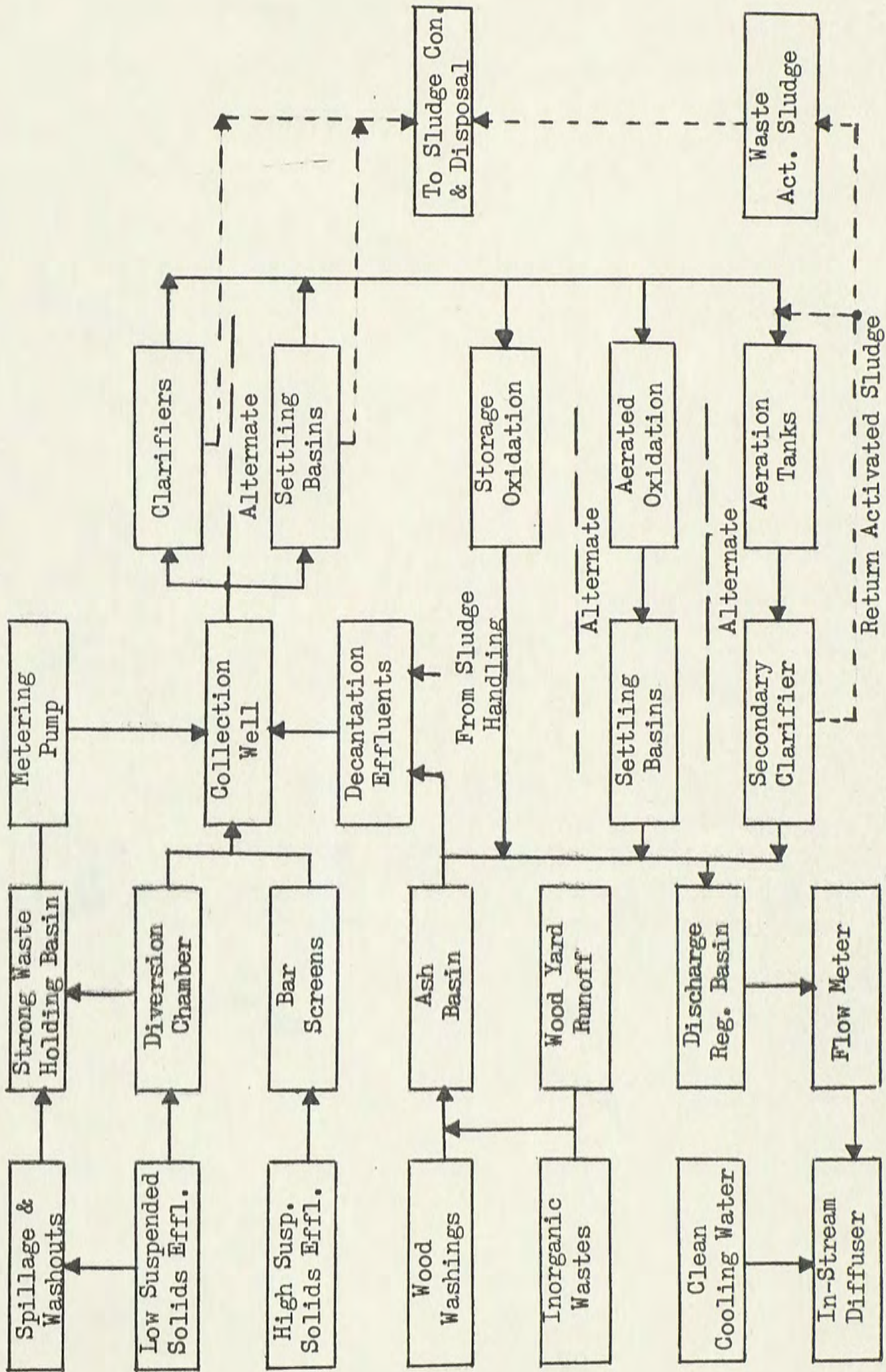


Fig. 6-7. Process Flow Diagram Mill Effluent Treatment (5)

concentrations were not successful in controlling the filamentous sulfide bacteria. The addition of chlorine to the return activated sludge did not control nonfilamentous bulking. Nitrogen and phosphorous additions were required to achieve satisfactory biological operation. There was no advantage in adding nutrient into the reaeration section as opposed to the contact section of the activated sludge process.

For satisfactory operation, dissolved oxygen levels of between 0.5 to 1.5 mg/l were required. It is more advantageous to bypass the primary clarification of mill wastes and add at the secondary stage.

During the period of operation the BOD, TSS, and colour removal averaged 91%, 78% and 19% respectively.

A recent pilot plant study (20) was conducted by Harriman Utility Board, Harriman, Tennessee, to establish design criteria, operating parameters, and the efficiencies of the biological processes for the treatment of combined municipal and NSSC pulp and paper mill wastewater in varying proportions. It also investigated, in detail, the technical problems connected with the treatment processes and provided first hand information on the treatment using extended aeration, high-rate biological filtration, high rate biological filtration followed by extended aeration, and the colour reduction ability of massive lime dosage. Other methods also were investigated.

Primary treatment of NSSC wastewater by settling in a primary clarifier showed reductions of 62% volatile suspended solids and an increase in BOD across the primary clarifier. The COD reduction

averaged 4% and showed some decrease in the organics. Primary treatment data are showed in Table 6-5.

A study on biofiltration revealed that the biofilter primarily acts as a "roughing" filter at the hydraulic and organic loadings as shown in Table 6-6.

The roughing filter function improved the downstream process efficiencies. Primary clarification of the raw NSSC waste improved the biofiltration efficiency. The biofilter was not effective in removing BOD from the combined wastewater with high percentages (greater than 80%) of NSSC wastewater. Although the study failed to detect the amount of excess sludge produced from the normal operations of the extended aeration process the major findings on the extended aeration pilot plant are as follows:

1. There were no appreciable performance differences due to changes in the percentage of NSSC wastewater. VSS removal of blended influent improved the quality of the effluent at a given unit process loading.

2. Of the three methods tested, biofiltration provided the greatest single improvement in effluent quality of the aeration basin at a given process loading.

3. Alpha and beta values of oxygen utilization depended greatly on the percentage of NSSC wastewater present and the values ranged from 0.42 to 0.88 and 0.42 to 0.93 respectively.

4. Oxygen requirements were determined to be 0.97 lbs. per pound of BOD removed plus 0.07 lbs. of oxygen per lb. of MLVSS in the aeration basin.

TABLE 6-5

PRIMARY TREATMENT DATA - NSSC WASTE MONTHLY AVERAGES* (20)

Month	Flow (GPD)	Infl. Volatile Susp. Solids (mg/l)	Infl. BOD (mg/l)	Infl. COD (mg/l)	Water Temp. (°F)	Volatile Susp. Solids	% Removal by ¹ Sedimentation		Sedimentation		
							BOD	COD	Det. Time (hr)	Overflow Rate (GPSFPD)	Solids Loading (lb/sq ft)
October	22,000	1,370	1,620	9,145	92	62	-17	8	7.0	254	3
November	16,600	925	1,945	9,320	81	50	-10	10	9.5	192	2
December	28,600	1,385	2,050	8,510	79	45	0	-5	5.3	330	4
January	26,500	665	1,890	7,240	66	76	-21	-15	5.9	306	2
February	23,400	865	1,825	8,660	73	70	-10	13	6.4	270	2
March	17,400	440	1,635	7,140	80	69	-9	13	6.6	201	1
AVERAGE	22,400	940	1,825	8,335	79	62	-11	4	6.8	254	2

April and May data omitted due to plant start up

¹June to October data omitted due to change in sampling procedure¹Negative values indicate increases in BOD and COD concentrations due to sedimentation

TABLE 6-6
BIOFILTRATION (20)

Biofilter Description	Hydraulic Loading mgd/acre	Organic Loading lb BOD/1000 CF
Normal High Rate Biofilter	10 - 30	80 - 100
Pilot Plant Bio- filter	48 - 102	100 - 400

Final clarifier performance has shown that lower temperatures reduce the performance of the clarifier. High suspended solids removal of 95%, and BOD removal of 85%, required an overflow rate of approximately 1,200 gpd/sq. ft. at 61°F. The same parameters, with temperature at 82°F, led to an overflow rate of 1,500 gpd/sq. ft.

At low loadings of the extended aeration basin the settling was enhanced considerably. At higher food to microorganism ratios the settling in the final clarifier would be hampered.

Paper mill wastes are noted for colour problems. Chemical precipitation with lime as a coagulant at various pH levels has been the most widely accepted method of colour removal. Increased dosages of lime on the NSSC wastes reduced the colour significantly. The lowest colour achieved was approximately 7,500 APHA units at 32,000 mg/l of lime. In the case of one to one wastewater and sewage mix, a lime dosage of slightly more than 22,000 mg/l gave the best colour quality. Chlorination of NSSC water after massive lime treatment reduced the colour to as low as 2,000 APHA units. These results are very well demonstrated by Figures 6-8, 6-9, 6-10, and 6-11, which are self-explanatory in demonstrating the effect of colour removal by lime, and chlorine dosages on NSSC wastewaters. Figure 6-12 shows the schematic for massive lime process for colour removed.

Disinfection studies on the same wastes revealed the following procedure for the most effective and economical removal of fecal coliforms.

1. Add ammonia at 40 mg/l and allow at least a 5 minute contact time.

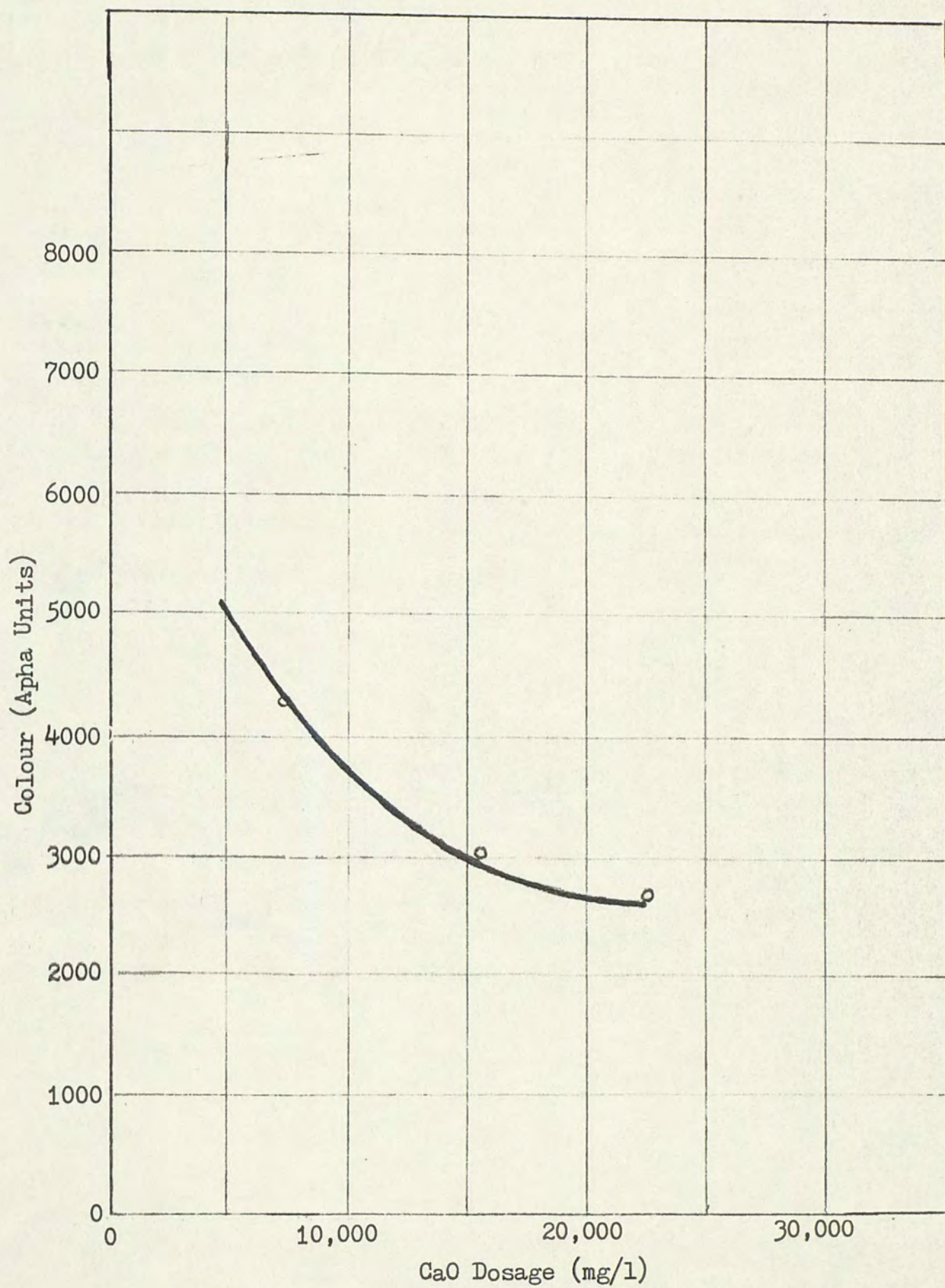


Fig. 6-8. Colour Removal and pH, 50% NSSC + 50% Wastewater

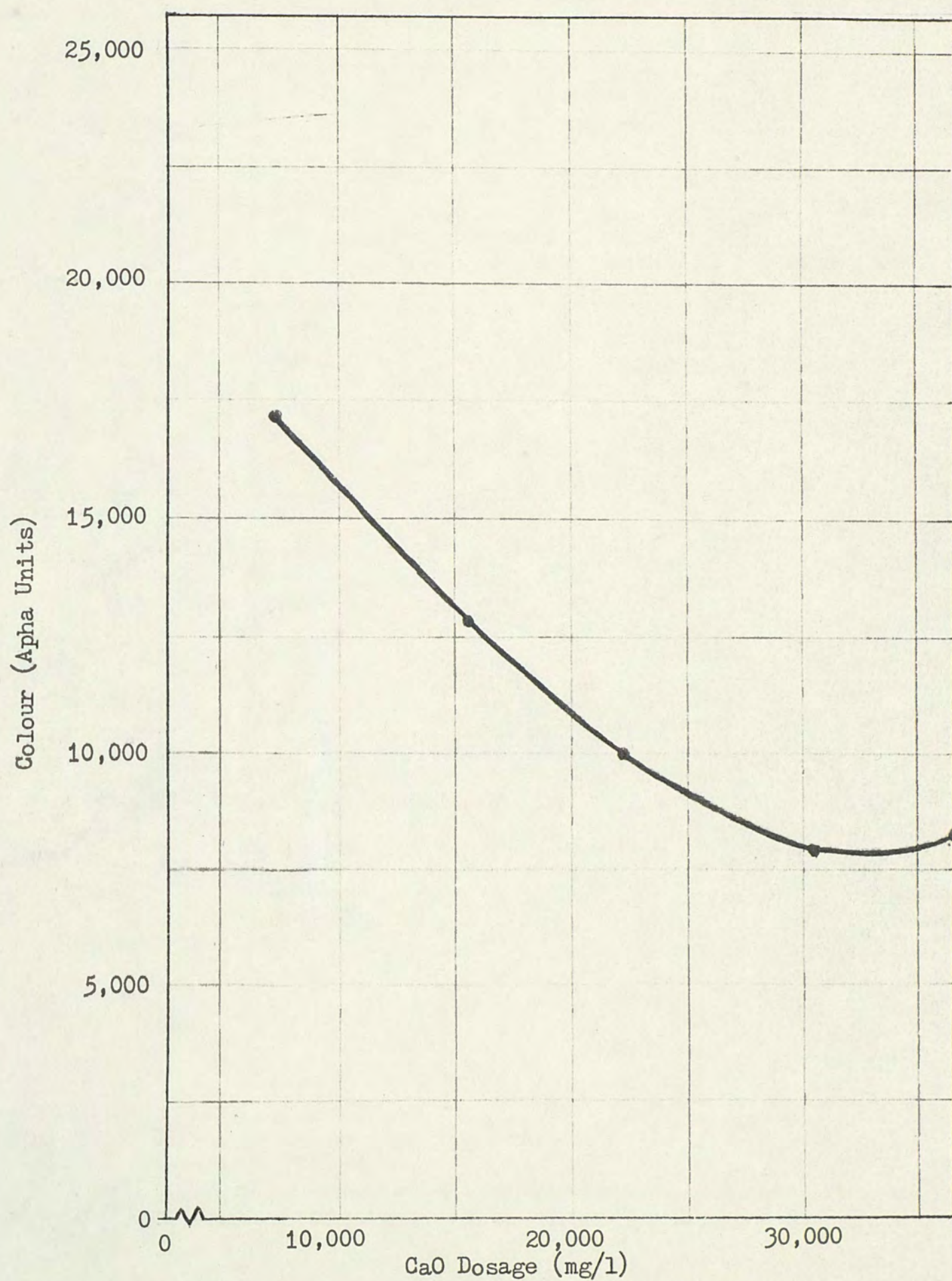


Fig. 6-9. Colour Removal and pH, 100% NSSC Wastes

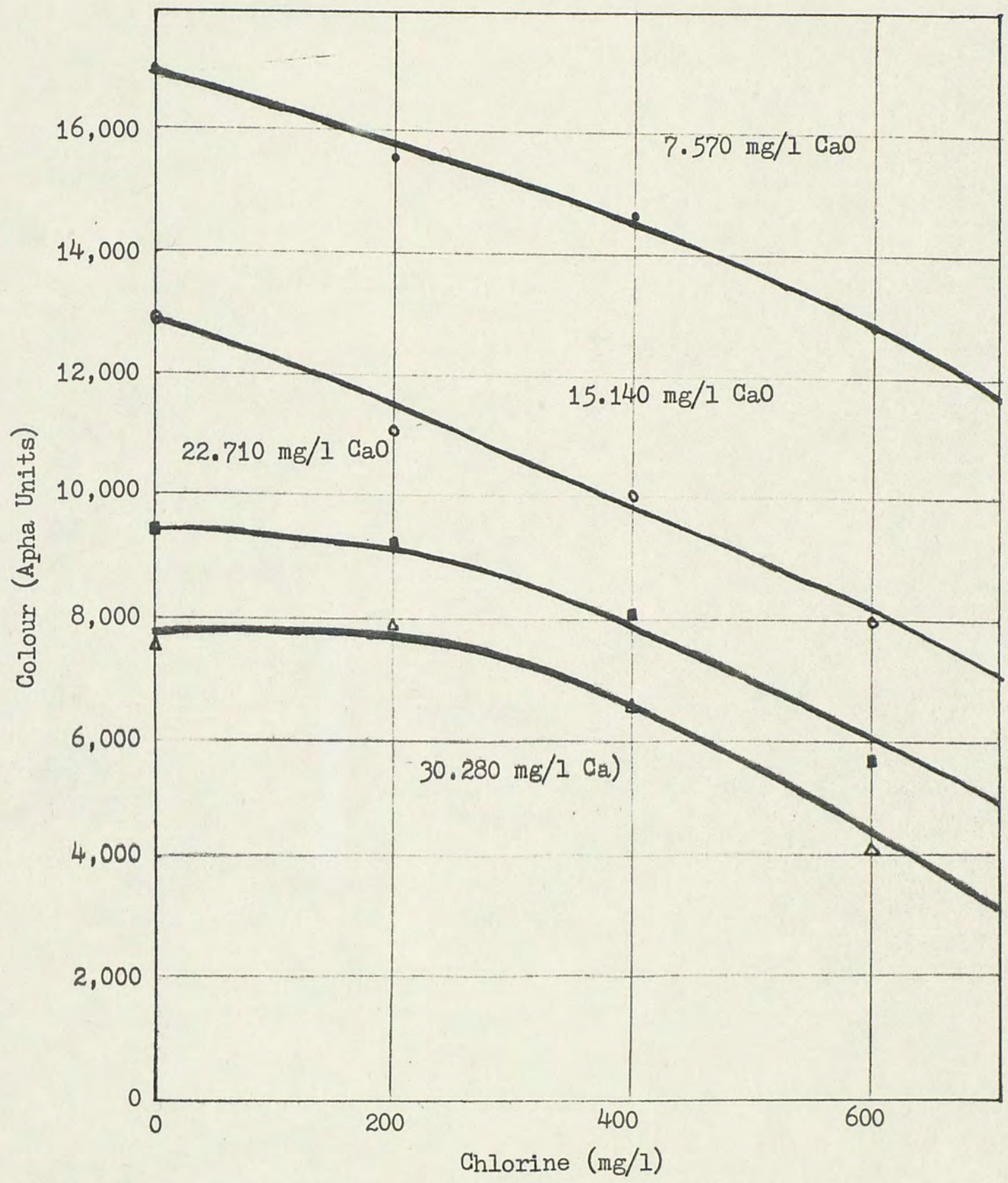


Fig. 6-10. Colour Removal and Lime + Chlorine, 100% NSSC Wastes

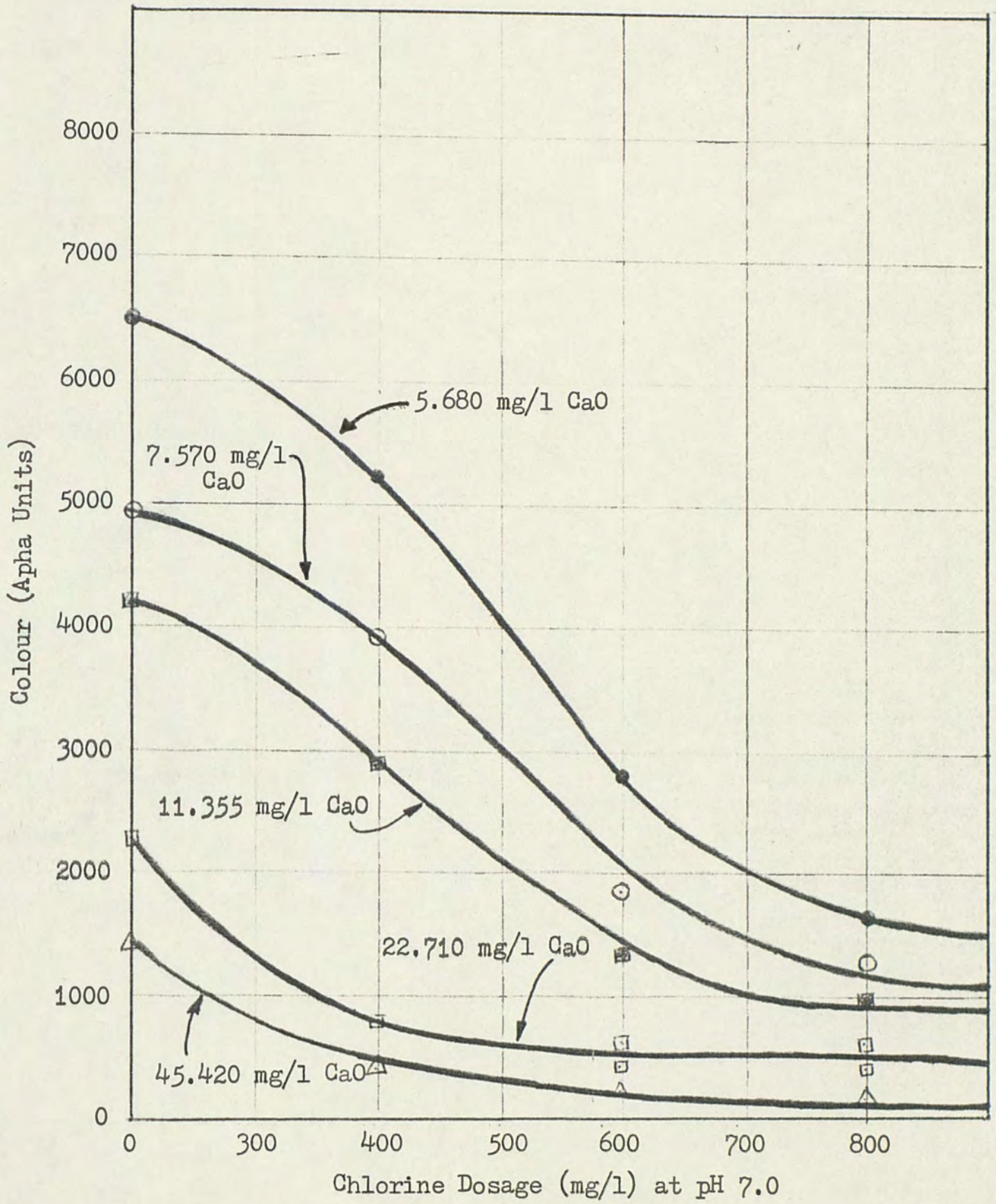


Fig. 6-11. Colour Removal and Lime + Chlorine,
50% NSSC + 50% Wastewater

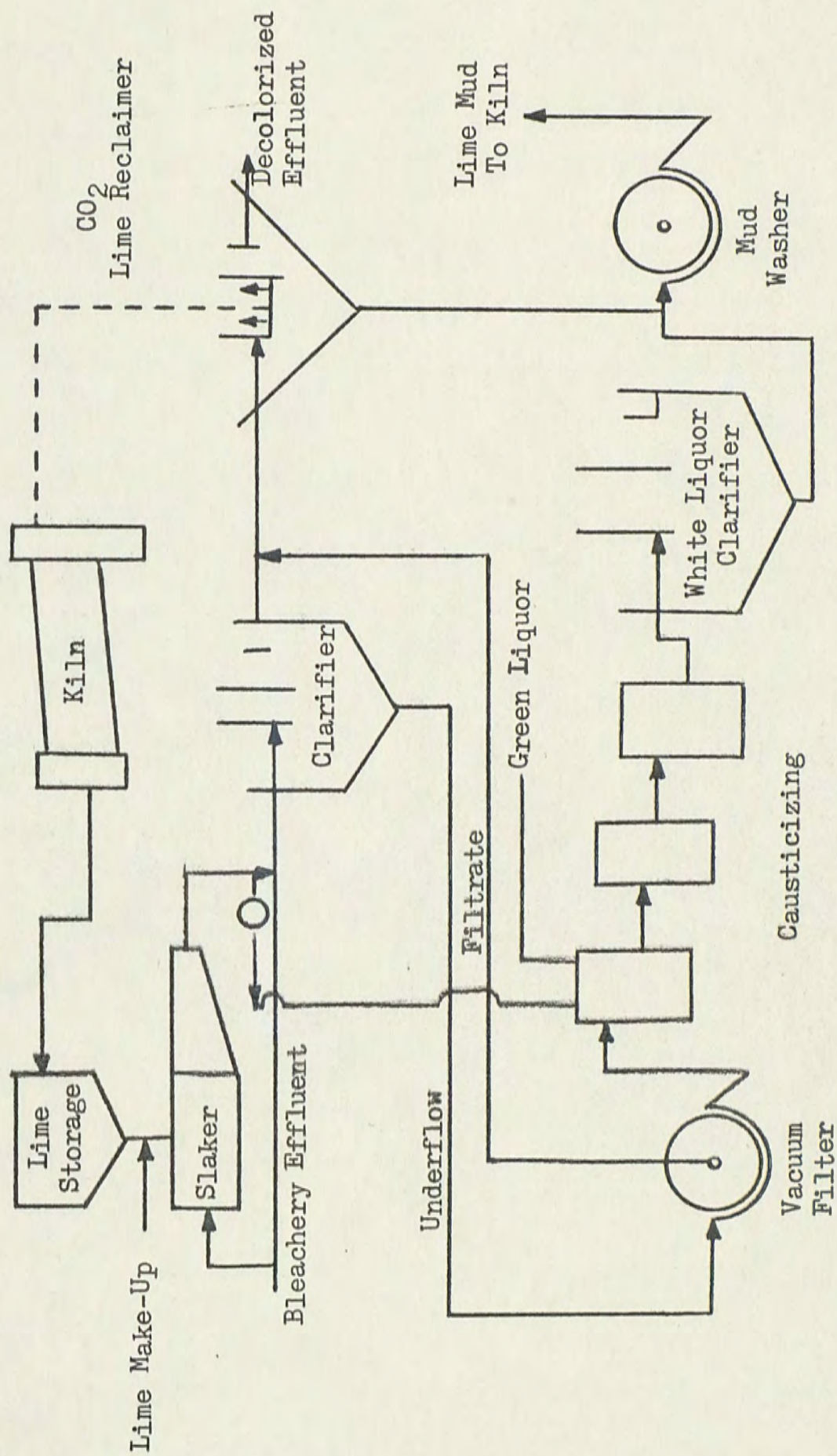


Fig. 6-12. Massive Lime Process for Colour Removal (5)

2. After the 5 minute contact time, chlorinate at a concentration of 20 mg/l.
3. Allow at least a 15 minute contact time.
4. Discharge as effluent.

A schematic of the flow process used for massive lime treatment by the industry is shown in Figure 6-12.

The use of activated carbon in the removal of colour is important. Pilot plant studies carried out by Lang, Timpe, and Miller in the National Environmental Research Center in 1975 has led to valuable results in this field (6). Unbleached Kraft mill effluent, treated by a sequence of lime treatment, or primary clarification plus bio-oxidation, or primary clarification followed by carbon adsorption in granular carbon columns, has been found to be suitable for general use in the mill.

Removal of colour to 100 APHA units and of TOC to 100 mg/l by the microlime carbon sequence requires maintaining a dissolved calcium concentration of about 80 mg/l (minimum of about 40 mg/l) by the use of about 80 mg/l of added CaO, no carbonation, and requires 2.5 lbs. of activated carbon per 1000 gallons effluent treated at contact time of 1.8 hours. At these levels, the microlime treatment alone removes 70% of the colour, compared to 85-90% at a dosage of about 1000 mg/l CaO in the minilime treatment.

The primary bio-carbon sequence provides reusable water quality at 10.5 lbs. of activated carbon per 100 gallons of effluent at a contact time of 3.8 hours. The capital cost of these requirements are too high for practical use in the treatment of wastewaters. How-

ever, this study shows the capability of activated carbon in cleaning grossly polluted waters.

CHAPTER VII

CONCLUSIONS

This research report reveals one neglected aspect of the management of natural resources in Srilanka. Srilanka, being aware of the environmental pollution problems encountered by industrially developed nations, should not keep a blind eye towards the pollution of fresh water resources by industrial effluents and agricultural runoff. The importance of a controlling authority with sufficient legislative backing is the first step towards pollution control activity. The massive amount of research work conducted towards water pollution control and the experiences already gathered by the Environmental Protection Agency of the United States of America could be used as a sample and a guide to plan out and solve the problems which are yet in the process of building up in Srilanka.

Pollution parameters mentioned under this report are mostly oriented towards industrial wastes. But the need of the times in Srilanka will not be limited to these aspects only. The pollution parameters due to agricultural runoff and salinity need to be included.

Today's environmental engineer not only has to be responsible for the management of natural resources but also will have to carry out his duties in the fields of legislative activity, control, and the planning of industry and national water resource control pro-

grams. The approach towards the end of pipe technology to treat industrial effluents is not considered practicable anymore. A sound knowledge of different industries, the allied processes, process chemicals and alternatives, is essential in solving the problems of industrial waste treatment. The choice of different methodologies for the treatment of industrial effluents depends on various aspects such as climatic conditions, cost, and the availability of land. Methodologies adopted in solving Srilanka's industrial waste problems will have to be decided only after a reasonably long pilot plant testing, or with reliable available data from tropical climatic conditions. Textile and pulp and paper industries are considered as major pollutant contributors with massive volumes of effluents.

Srilanka's present day industrial development by the use of cottage industries of textile and pulp and paper origin together with medium-sized industrial complexes, will have to be controlled by a pollution control authority.

The methodology adopted in investigating the industrial processes and inplant control techniques, etc., will have to be carried out in detail for all of the industries of Srilanka, at least in order to specify regular methodologies for treatment, and in keeping an open eye on the use of new machinery to be used in the expansion of the available industries and new industries.

Use of lagoons for the treatment of industrial effluents will be practicable in the areas where clayey soils are available. Treatment of industrial wastes, together with municipal sewage, in the thickly populated areas would be reasonable.

Availability of lime and cheap activated carbon within the country is of considerable use for the treatment of industrial wastes. Production of good quality activated carbon from coconut shells and coconut husks could not only act as a saviour of Srilanka's water resources but also will have considerable use in solving the world's water pollution problems.

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