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A survey of industrial water pollution in the pulp and paper industry of the United States.

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A SURVEY OF INDUSTRIAL WATER POLLUTION
IN THE PULP AND PAPER INDUSTRY
OF THE UNITED STATES

A Dissertation Presented

By

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A SURVEY OF INDUSTRIAL WATER POLLUTION IN THE PULP AND PAPER INDUSTRY OF THE UNITED STATES

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PREFACE

Over the past few years many people have become increasingly cognizant of the problem of water pollution. Along with awareness often comes a desire to find out why or how pollution originated, and what can be done to stop it. Such a desire developed in me with this paper as a result. In my quest for resolving the many and often unanswerable questions one encounters, I was fortunate in having the help and guidance of several people.

I would like to thank Bernard B. Berger, Professor of Civil Engineering and Public Health and Director of the Water Resources Research Center, for his tremendous help in many areas of technical concern, as well as with questions of a legal nature. Thanks also to Mary Barber, Assistant Professor of Marketing, for invaluable help in organizational, economic and structural problems encountered as well as for the encouragement needed to solve them. Special thanks to the Chairman of the committee, Arthur Elkins, Associate Professor of Management, for help, time, and energy that words could not adequately explain.

In addition I would like to thank Robert P. Gleason, Head of Environmental Health and Safety at the University of Massachusetts, for his insight, knowledge, and many hours of time spent in helping me with this report. Finally I would like to thank the most patient and understanding person of all, my wife Peggy.

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CHAPTER I

INTRODUCTION

Water pollution is a difficult term to define. A simple definition may be that water pollution is any process that imparts impurities into the water. This definition is by no means complete. Some authorities disagree as to what is considered polluted water. Some argue that only man-made or man-induced pollution is included in the definition. Others argue that water is polluted only when a detrimental social effect of dirty water exists; that is, if the water is dirty but harms no one, it is not polluted.

Perhaps the defining of water pollution is best served by describing how the water becomes polluted, exploring the nature and severity of the polluting materials, or explaining the effect of the pollutants on the body of water.

Throughout the report attention will be given to various processes, activities, and pollutants that disturb the natural ecological balance. This report will describe how man has attempted to eliminate one form of water pollution - industrial wastes from the pulp and paper industry. Certain generalizations concerning the nature and causes can be applied to other industries. In this way the survey can serve as an example in furthering understanding of industrial water pollution and its causes.

The survey is structured such that discussion is broken into three main categories: 1) the extent and reasons for water pollution, 2) industrial water pollution control measures, and 3) possibilities for water conservation and anti-pollution measures. The first section deals with a gross overview of water pollution, followed by a discussion of the self-purification process of a stream. Still in the same section is a rather thorough but brief description of the process of producing paper including various methods of pulping. Along with this description is a part dealing with the various effects of the pollutants and means of measuring their effects.

The second section of the survey is considered with industrial water pollution control measures. Included in this section is a presentation of industrial processing techniques, specifically dealing with pre-treatment and biological waste treatment processes. Of special interest in this section is the part on the government's effect on industry. Here the reader will learn of various legislative measures and how, if at all, or when the legislation has affected pollution levels. Also considered is the influence exerted by the public especially concerning consumer coalitions or action groups and their sometimes dramatic effect on pulp and paper mills. Last but not least intra-industry co-operation is considered in an attempt to show how the management is or is not influenced in its decisions by stockholders and customers.

Various social and economic points are considered in the third section. Included in these points are discussions of: the social responsibility of a firm, social costs and private costs, various market mechanisms, possible regional water quality commissions, as well as zero growth and its ramifications.

Recycling and reusing of water is discussed as is the feasibility and practicality of installing a recycling system. Coupled with this is an investigation and several examples of selling by-products obtained from wastes, and how by-products tend to recover the costs of capital equipment. A brief discussion of recycling paper is also included.

Through these three sections one can get a basic idea of the complicated process and procedure necessary to reduce the levels of industrial water pollution. As will be shown, until recently the populus was not aware of the severity of the problem. But this report sheds light on possible solutions and gives the reader a better understanding of some of the complex areas of industrial water pollution.

CHAPTER II

EXTENT AND REASONS FOR WATER POLLUTION IN THE PULP AND PAPER INDUSTRY

To clean up the streams and lakes in the United States would cost a tremendous amount of money. Figures ranging from $5 billion to $50 billion are not uncommon as estimates of the damage done and the cost to repair the damage. Even with an expenditure of $50 billion, however, there is no guarantee that certain bodies of water can ever become "healthy" again. Industrial processes contribute 31 trillion gallons of waste into waterways while government in the form of municipalities contributes 14 trillion gallons of waste into waterways. Simple control and care of water pollution costs the nation an estimated $12 billion per year. The pulp and paper industry alone spends better the $500 million annually on water pollution.[1]

Several questions that now come to mind are how did all of this come about; how could man allow his rivers and lakes to become so polluted? To properly answer these questions we must go back a few years and realize how people viewed pollution. At the turn of the century a lot of people seemed concerned about making money, producing more products, and

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1. Harold Wolf, "Pollution Price Tag: $71 Billion," U.S. News and World Report, Vol. 69, August 17, 1970, p. 38-41.

inventing new processes. They were simply unaware of the consequences of these and other acts. There are many general examples to support this statement: the wanton annihilation of the buffalo for food, clothing, and even sport; the destruction of many forests and their accompanying beauty for the railroads, new houses, and pulp and paper mills; the haphazard disposal of polluting effluents into adjacent streams. There appeared to be no public awareness of the ultimate consequences of these and other acts. The only people concerned about these affairs were the conservationists who fought against the upset of the balance of nature but to no avail.

So people did not concern themselves with polluting the water. In a nation well on its way to becoming the industrial giant of the world who was to worry about water pollution?

The Federal government had no legislation on its books regarding water pollution until 1899 when Congress passed the Rivers and Harbors Act. In retrospect this piece of legislation did little to prevent water pollution, but then again it was not designed to prevent pollution. The purpose of the bill was to prohibit the disposal of garbage that impeded navigation. To this end it succeeded, but this and some following legislation of the same kind had little effect on the dumping of municipal and industrial wastes into waterways.[2]

It seemed as though there was no one who would or could take an interest in water pollution except the conservationist.

Let us assume that the conservationist is some sort of scientist, say a chemist or biologist. No matter how vehement the man may feel against water pollution only a limited amount of technology was available. Many of the technological advances we take for granted today were new or were not available or were viewed with comparative ignorance at the turn of the century. The process that allows us to disinfect water by chlorination is fairly new in that its discovery was not applicable on a large scale until 1908.[3] Thus, even though the people at that time may have been concerned, they were technologically unprepared to prevent water pollution.

Stream Self-Purification

One method of combating water pollution was present. Nature herself cleans the streams and rivers in a process

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2. "The Annual Report of the Council of Economic Advisors, 1966," reprinted in part in Marshall I. Goldman, Controlling Pollution, Prentice-Hall, Englewood Cliffs, 1967, p. 171.

3. E. F. Eldridge, Industrial Waste Treatment Practice, McGraw-Hill, New York, 1942, p. 12.

known as self-purification.[4] The purification process of a stream takes place in a series of steps:

1. Wastes discharged into a stream may have an immediate oxygen demand upon the stream because of the nature of the waste. Some chemicals in the waste may unite chemically with the oxygen in the water, but most, however, must be decomposed by microorganisms.

2. Materials suspended in the waste such as settlable solids become deposited on the bed of the stream, causing formation of sludge beds.

3. Colloidal or soluble organic material is utilized by the stream organisms with the result that a decrease in dissolved oxygen (D.O.) content takes place. This is known as aerobic decomposition and proceeds as long as oxygen remains in the water.

4. If no oxygen is available, acquatic life will die and anaerobic decomposition occurs. Anaerobic decomposers are mainly bacteria that utilize chemically combined oxygen for survival. The various organisms reduce or oxidize all materials to a liquid or gas state.

Numerous factors affect the self-purification of a stream. Since most of the processes are biological in nature, factors affecting the organisms are most important.

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4. E. F. Eldridge, Industrial Waste Treatment Practice, McGraw-Hill, New York, 1942, p. 12.

Each type of organism has conditions that are optimal for growth and development. Some of these factors include the amount of light, the kind of food, the temperature of the water, and naturally the amount of oxygen. As these organisms decompose materials like wood sugars from pulp mill effluents, the amount of dissolved oxygen decreases. The problem is basically to allow sufficient oxygen to be restored to the stream so that the organisms can continue to decompose the waste.

Oxygen is restored to the water in a variety of ways.[5] As it moves along, especially in a fast moving stream, the water is reaerated thereby raising the dissolved oxygen content of the water. In certain streams water plants by photosynthesis produce oxygen just as do land plants. However, at night no new oxygen is formed in the absence of the sunlight. Not only is the level of D.O. reduced in this manner, but some of the algae die, and their tissue must also be decomposed. The amount of dissolved oxygen is lowest just before dawn. This indicates in part the interplay between oxygen and water pollution. To the extent that air pollution creates smog and blocks out the sun's rays, the oxygen content of the water is not restored by photosynthesis. Such is also the case with clouds.

Assuming that the stream is moving fast enough and

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5. "What is Pollution," Goldman p. 60.

that no new effluents are added to the waterway, the stream should be able to cleanse itself of organic waste and restore dissolved oxygen by natural tumbling and aeration. Historically self-purification of a stream is the only process that cleaned the water. As the population, the resultant productivity, and the pollution increased, this method had to be supplemented with artificial means.

To better understand the nature of the pollutants and the damage caused by the pulp and paper industry, perhaps a description of some of the processes causing the pollution should be presented. The next section attempts to explain briefly but thoroughly the processes and the points from which polluting effluents originate.

The Process of Producing Paper

Cellulose is the basis of all paper. The source of cellulose is the tissue from a large variety of plants. Since plant tissues are composed of cells and cellulose fibers, it becomes necessary to remove the cells from the fibers prior to the manufacture of the paper. This process of preparing the fibers for paper manufacture is known as pulping.

Paper production is, therefore, divided into two distinct operations: 1) the preparation of the fiber in the pulp mill and 2) the actual manufacture of the paper in the paper mill. These mills may be separate, in which case the pulp mill is concerned only in the production of pulp that is sold to the paper mills. In many cases the two mills are combined, the paper-making following the production of pulp in more or less continuous and related operations. In the following section the mills will be considered as two distinct operations, although we will consider a combined operation in other sections of this report.

Pulp is made from a large number of raw products such as wood, straw, rags, wastepaper, threads, textile cuttings, and other materials rich in cellulose.[6] The more important processes are those used in preparing the pulp from wood, rags, wastepaper, and straw. These will be discussed here mainly for the purpose of pointing out the sources of the major wastes.

Production of wood pulp. Four main processes are used for the manufacture of pulp from wood: the mechanical or groundwood, the sulfite, the sulfate or kraft, and the soda. Each process produces a pulp with characteristics desirable for certain grades of paper.

The mechanical process. Mechanical or groundwood pulp is produced for the manufacture of the cheaper grades of paper, such as newsprint, cheap Manila, wrapping paper, and building

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6. C. Earl Libby, Pulp and Paper Science and Technology, Vol. II, Paper, McGraw-Hill, New York, 1962, p. 12-13.

papers.[7]

Spruce, balsam, and poplar are the types of wood generally used. The logs are cut, the bark is stripped, and as many of the knots as possible are removed. The logs are then worked on by a grinding machine. Hydraulic pressure is employed to maintain constant contact with the grinding stone. A constant flow of cooling water is maintained to prevent overheating of the stone and burning of the fiber.

The fibers formed are coarse and irregular. They are then separated by screens according to relative size, after which the larger pieces are further ground. The smaller pieces are run into refiners where they are squeezed and ground between stones to form a consistant pulp.

The small waste that originates from this process is mostly water which contains pulp. By reusing the waste water considerable savings in pulp can be realized; in addition, the pollutants can be effectively eliminated.

The sulfite process. Figure 1 on page 12 is a flow diagram showing the major units of the sulfite pulp mill. In this process[8] sulfur dioxide (SO_2) dissolved in calcium bisulfite ($Ca(HSO_3)_2$) or magnesium bisulfite ($Mg(HSO_3)_2$) is

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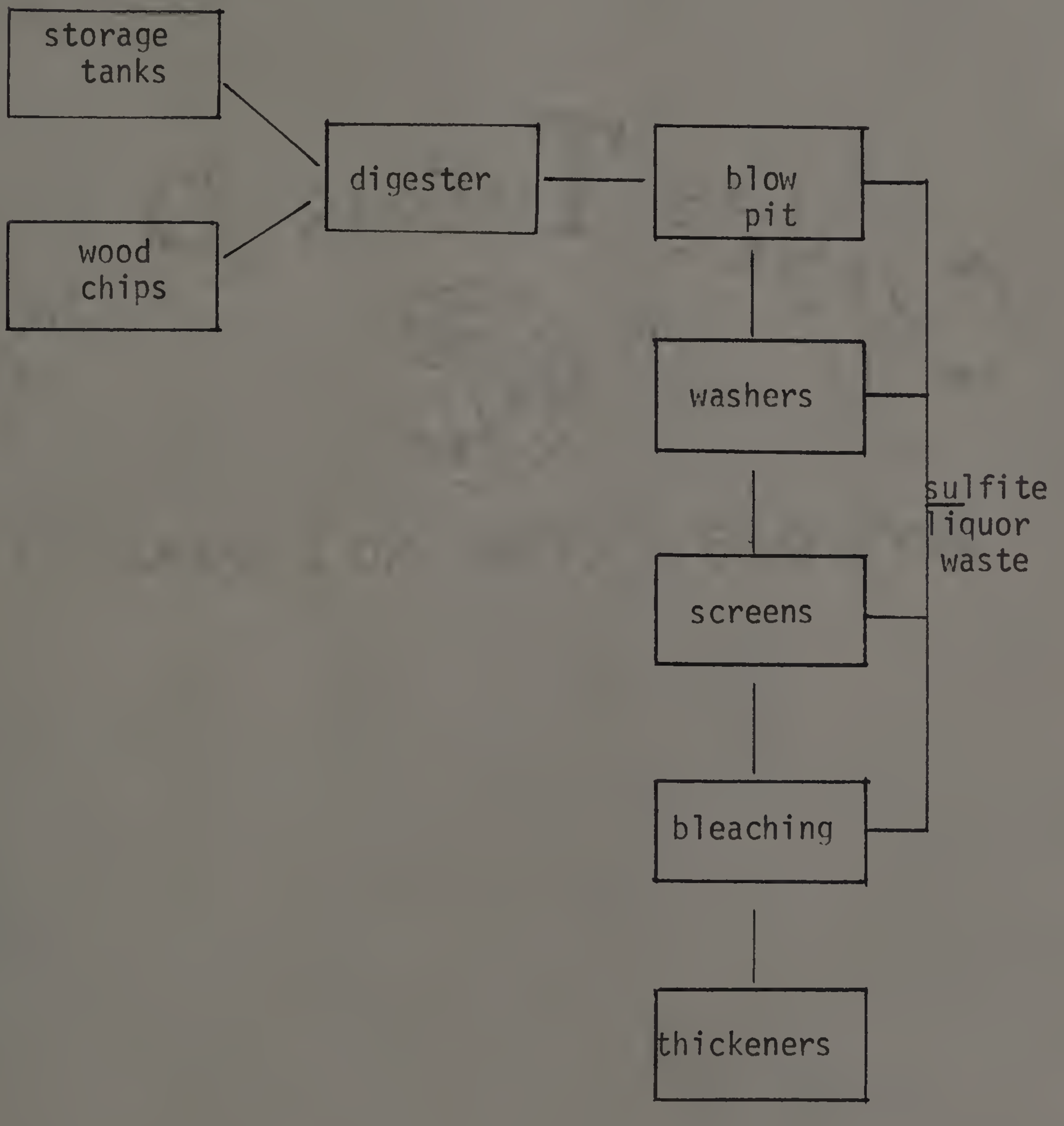
7. Britt, Handbook of Pulp and Paper Technology, Ed. 2, Van Rostrand Reinhold Co., New York, 1970, p. 179-188.

8. ibid., p. 160-165.

used to produce the cooking liquor which is stored in tanks until needed. The wood chips and cooking liquors are mixed in large steel digester tanks. The mixture is cooked with



Flow Diagram of the Sulfite Process[9]

live steam for a period of from 8 to 12 hours. The contents of the digester are dumped into a blow-pit having a perforated floor through which the liquor passes. The mass is washed to

9. Eldridge, p. 201, somewhat modified.

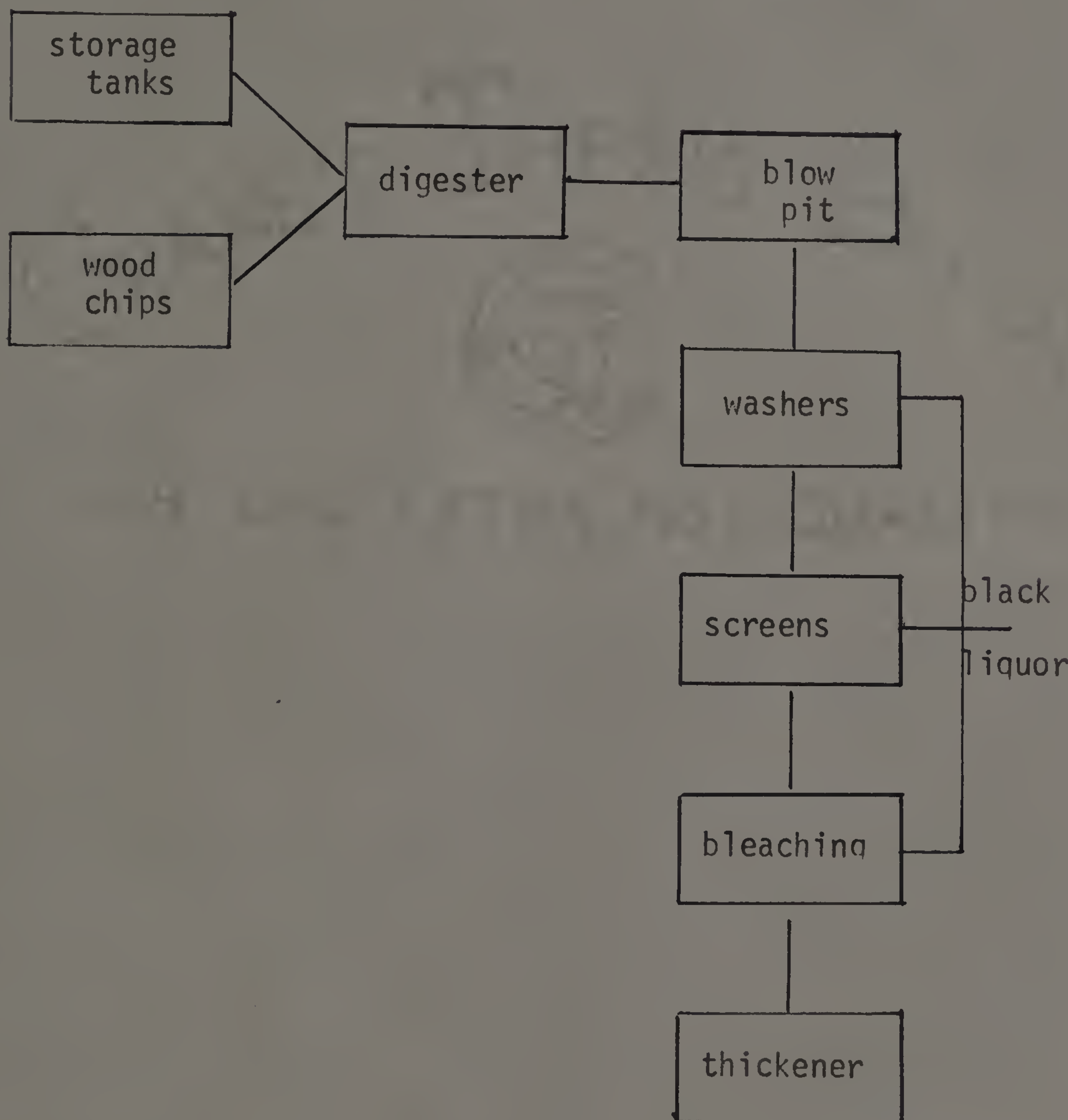
remove the strongest of the remaining liquor and is passed to the screens. Here knots and larger particles are removed, after which the pulp is passed to store chests.

The sulfite waste from the blow-pits constitutes one of the strongest of industrial wastes. Many attempts have been made to utilize the waste with varying success. The non cellulose compounds that have been dissolved by the liquor represent more than 50 per cent of the weight of the wood. They are composed of lignins, carbohydrates, and resins. The exact chemical composition of these ingredients is not known, although certain substances have been isolated. About 1.2 tons of solids are produced from the manufacture of 1 ton of pulp. This is contained in about 9 tons of waste sulfite liquor.

The pulp from the process is washed and converted into "half stuff" in a thickener. If a bleached stock is required, the pulp is subjected to the action of bleaching powder or liquified chlorine or lime, after which the excess chemical is removed by washing. If the pulp mill is not combined with a paper mill, this "half stuff" is converted into boards and packed in bales for shipment.

Other sources of liquid waste from the sulfite pulp mill are the water from the screens and thickeners, and the excess bleach liquor, and washings from the bleached pulp. These waters contain some dilute sulfite liquor, fine pulp, and the chemicals used in the bleach.

The sulfate process. Figure 2 on this page is a flow diagram showing the major units of the sulfate (kraft) pulp



Flow Diagram for the Sulfate Process[10]

mill. Over the years the sulfate process has been the principal method for the production of pulp from wood.[11] The essential feature of the process is the recovery of the chem-

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10. Arthur Stern, Air Pollution, Vol. III, Sources of Air Pollution and Their Control, Acedemic Press, New York, 1968, p. 245.

11. Britt, p. 135-142.

icals from the waste cooking liquors. Sulfate pulp is known as kraft and produces a paper of high strength but of poor color. This pulp is used largely for wrapping paper, bags, and other high strength but low quality uses.

Caustic soda (NaOH) along with sodium sulfate (Na_2SO_4) are the active ingredients found in the cooking liquor of the kraft process. The wood chips are introduced into large digesters along with the cooking liquor. The cooking is accomplished under pressure with live steam for a period of from 2 to 6 hours. The material is then dumped onto the perforated floor of the blow-pit where the liquor drains from the pulp. Much of the liquor that remains in the pulp is removed by washing with hot water. These washings together with the liquor that has drained from the pulp is known as "black liquor" and is passed to storage tanks called save-alls. The pulp is screened, washed, thickened and sometimes bleached. It is then converted into boards that are baled for shipment.

The black liquor contains the chemicals in a rather dilute condition. The liquor is evaporated and the solids burned producing a black ash. The black ash is mostly crude soda ash (Na_2CO_3), sodium carbonate. This is then mixed with fresh soda ash producing what is known as "green liquor." The carbonate is converted to caustic soda by treating the green liquor with quick lime (CaO). This mixture is settled and filtered, producing "white liquor" which is then ready for cooking.

Carbon (C) and calcium carbonate ($CaCO_3$) are the chief by-products of the recovery in the soda and sulfate processes. The carbon is activated and used commercially as a decolorizing agent. Lime is burned and reused or may be marketed as agricultural lime.

Although there is no black liquor waste from the sulfate mills, some of the chemicals and organic substances are contained in the wash waters. The sources of these wastes are the washers, screens, thickeners, and in some cases the bleach. The wastes contain fiber, bleach, chemicals, and the compounds from the black liquor washings.

The soda process. The soda process[12] is identical to the sulfate process in the chemicals involved and the mechanisms employed for producing pulp with one exception. The soda process does not use sodium sulfate just caustic soda, thus eliminating a lot of the foul-odored sulfur compounds produced in the sulfate process.

The soda process is used primarily for the pulping of wood from deciduous trees, those whose leaves die and fall off in the autumn. This is unlike the sulfate or sulfite process in which coniferous woods such as pine and spruce are pulped. The soda process produces a soft paper mainly found in books and magazines.

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12. Britt, p. 135-142.

Production of Wood Pulp in the U.S., by Process and Year[13]
(per cent of total population)

Process	1940	1945	1950	1955	1960	1965	1970*
Mechanical	18.2	18.0	14.9	13.2	13.0	11.8	
Unbleached sulfite	11.1	8.0	5.0	3.1	2.1	1.5	
Bleached sulfite	18.0	15.2	14.2	13.9	12.6	11.4	
Unbleached sulfate	35.3	35.6	38.4	37.0	34.3	35.4	
Bleached sulfate	6.5	8.4	12.1	17.5	23.3	26.3	
Semi-chemical	a	a	4.6	6.8	7.9	8.7	
Soda	5.9	4.2	3.5	2.1	1.7	0.7	
All other	4.9	10.6	7.2	6.4	5.2	4.4	
Total	99.9	100.0	99.9	100.0	100.1	100.2	

* not available
a reported in "all other" for 1940 and 1945.
b total production increased from 8.96 million short tons in 1940 to 33.3 million short tons in 1965.

Old paper stock. The practice of recycling or reusing old paper to produce more paper has developed in this country to the point where it exceeds almost all other sources of pulp for the manufacture of certain grades of paper.[14] More about this practice and the process employed will be discussed in a later section of the report. It is sufficient to mention now that the process is vaguely similar to the soda process.

The liquid wastes from the production of old paper stock

13. American Paper and Pulp Association, Statistics of Paper 1964. p. 10, and American Paper Institute, Statistics of Paper, 1966 Supplement, 1966, p. 2.

14. James P. Casey, Pulp and Paper, Ed. 2, Interscience Publishers Inc., New York, 1960, p. 373-374.

consist of wash water from the washers and thickeners and the bleach liquors and washings. These wastes contain most of the spent chemical from the cooking and bleach, fine fibers, and the sizing, caesin, clay, ink and dyes along with other compounds removed from the paper stock. The weight of these materials is from 20 to 24 per cent of the weight of the old paper.

Rag stock and straw stock. Rag stock is said to constitute the ideal material for the manufacture of high-grade paper.[15] Clean cotton and linen cloth go into a class of paper known as "fine writing." Low grade rags, burlap, and hemp rope are used in making roofing and wrapping paper. Rag stock is ideal because the fibers comprising the stock are almost pure cellulose free from most impurities.

Wheat, rye, and oat straw are used for the production of yellow-straw pulp. Yellow-straw pulp is used for the manufacture of straw-board, corrugated paper, and a large number of different types of containers. Bleached-straw cellulose is used for the making of fine writing papers.

Due to the relative scarcity of these products not a great deal of paper is made from pulp of rag stock or straw stock. The paper that is produced from these pulps is generally of the fine writing quality and is comparatively expensive.

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15. ibid. p. 397-401.

Process of paper manufacture. Half stuff or pulp manufactured in the pulp mill is the basic material used by the paper mill in the manufacture of paper.[16] This half-stuff has been washed, bleached, and partly defibered, as the case requires, but lacks uniformity. The paper mill refines this material and works it into the desired type of paper. Figure 4 on page 20 is a flow diagram of the major operation of a typical paper mill.

The pulp or half-stuff or any desired combination of the basic ingredients is loaded into the beaters. Clays, or other loading material, dyes, sizing, and other additional products are some of the materials now in the beaters with the pulp. The materials are passed under a rotating cylinder equipped with dull knives that beat and break up the bunched fibers to a fairly uniform size.

After the beating operation the "stuff" may be refined in other beaters or passed to separate machines for refining. The refiners or Jordans consist of a tapered knife-equipped cone rotating in a close-fitting casing in which more knives are embedded. This operation brushes out the fibers and reduces them to an even more uniform length.

From the beaters or refiners the stuff is discharged into a storage or stuff chest capable of holding upwards of 1,000 pounds of pulp. The purpose of the chest is to allow

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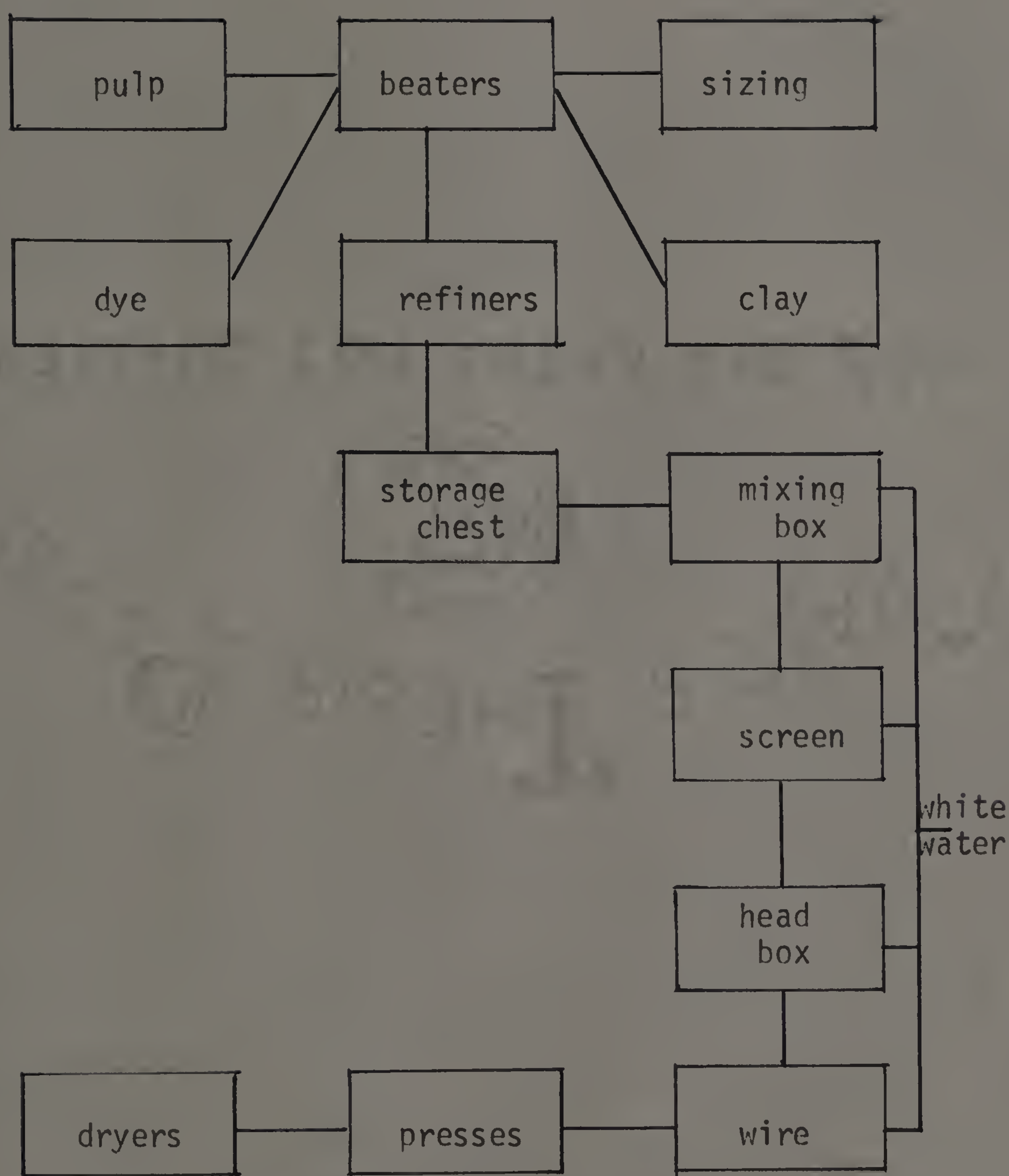
16. The material on the manufacture of paper comes from several sections of Casey, p. 586-590, p. 722-725, and p. 753-770.



Flow Diagram of Paper Manufacture[17]

the paper machines to receive a uniform flow. There is no continuous waste from the beaters, refiners, or chest. The waste that is present, known as "white water", contains considerable fiber but is small in volume.

From the stuff chest the material goes to a regulating or mixing box, where the stuff is diluted to the proper

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17. Eldridge, p. 216.

consistency for application to the machine. The stuff is then passed over rifflers or sand traps and from there to the screens. The screens remove materials improper in size and impart an evenness and regularity to the finished paper.

The stuff then passes direct to the paper-machine wire or to a head box at the upper end of the machine from which it is fed to the wires. The pulp, as it reaches the wires, contains from 97 to 99 per cent water. The wires form an endless belt that move rapidly and are made of a fine mesh. As the stuff is fed onto the wire, most of the water passes through, leaving the fibers spread in a uniform mat on the wire.

It is essential that most of the water be removed from the web before it reaches the felts, since it must support itself for a short distance in the transfer from the wire to felt. To accomplish this two or more suction boxes and a suction roll are placed near the end of the wire. Showers of clean water are directed at the web as it forms and travels down the wire.

After transfer to endless felts, the web passes between suction rolls or couch rolls and wet presses to remove excess moisture. It is then passed in a sheet between drying cylinders and eventually between calenders, where it is given the desired smoothness. The paper is then cut and rolled.

THE MEASUREMENT AND EFFECTS OF POLLUTANTS

Now that we have a basis for determining where the pollutants originate and how they enter the receiving water, we can next examine the harmful effects caused by the pollutants. Each process has its own distinctive effluent. The effluent from some processes causes more harm than that of others: eg: the sulfite pulping mill wastes vs. the paper mill wastes. Basically though, the effluents from any of the processes are somewhat similar.

Fresh water supports many forms of life that undergo complex biochemical processes to survive.[18] In order to support these processes and maintain the living organisms there must be a certain amount of dissolved oxygen in the water. The generally accepted minimum level for dissolved oxygen is 5.0 to 7.0 p.p.m. (parts per million) to maintain normal growth conditions for fish. While oxygen is present aerobic decomposition is the principal means of eliminating organic waste. If no oxygen is present, septic conditions prevail, and anaerobic decomposition proceeds.

The process of anaerobic decomposition while inherently complex may be presented simply. The organisms are now forced due to the low level of dissolved oxygen to search for oxygen elsewhere. Other sources dissolved in the water such as sulfates, phosphates, and nitrates have oxygen chemically

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18. Much of the material in this section is from Casey, p. 832-875.

combined in their make-up. The organisms utilize the oxygen available in these chemicals but often produce as by-products foul-smelling substances such as hydrogen sulfide or some oxides of phosphorous.

Uncontaminated water in rivers, streams, or lakes have dissolved oxygen in excess of the minimum level required. But when the water becomes contaminated with organic matter such as wood sugars in kraft waste, the organisms oxidize this material. The result is a decrease in decomposable waste but also a decrease in the amount of dissolved oxygen. In other words organic matter has an oxygen demand which upsets the oxygen balance of the stream. If this foreign matter is present in sufficient quantity it can lead to total reduction of the oxygen supply with accompanying destruction of fish and plant life. If the waste in the stream is not excessive in quantity, the natural purifying effect of the stream will keep the oxygen in balance. On the other hand, if the waste is greater than that load the stream can assimilate, the oxygen content may be lowered to dangerous levels. Since a certain amount of time is required for the oxygen demand to develop, the greatest depletion of oxygen occurs at some point downstream from the mill site, often several days' flow. By suitable analysis, it is possible to compute the maximum biochemical oxygen demand (B.O.D.) of the mill waste which the stream can accept without excessive oxygen depletion of the stream. The B.O.D. gives information on the oxygen depleting potentials of mill wastes in natural streams.

B.O.D. is really a measure of the oxygen utilized by the microorganisms only. Certain inorganic substances, eg., sulfurous acid found in waste sulfite liquor, consume oxygen and increase the total oxygen demand. These materials consume oxygen very rapidly. Their demand for oxygen is referred to as chemical oxygen demand (COD). If the volume of flow of the waste liquor is not known, the B.O.D. is commonly expressed in terms of population equivalent per ton of product produced. A population equivalent is the 5-day oxygen demand of the waste discharged daily by one person, and has been estimated at 0.167 pounds of B.O.D. per day.

The overall effluents from a pulp and paper mill can be divided for convenience into the wastes from the pulp mill and those from the paper mill. Paper mill effluents, unlike pulp mill spent liquors, are fairly low in dissolved organic matter, but are generally high in suspended matter which may be organic (fiber) or inorganic (filler). The suspended matter represents valuable fiber and pigment, and for reasons of economy, most paper mills recover and reuse a large portion of the wastes.

As waste, untreated white water from a paper mill is undesirable because the suspended organic matter causes turbidity and discoloration, and may result in sludge deposits. The organic matter may also decompose either in suspension or in sludge deposits, thus depleting the dissolved oxygen in the stream. Some materials present in even small amounts will result in a "milky" appearance to paper mill waste and produce unsatisfactory appearance to the receiving stream. For this reason and for the reason of economy, paper mill white water is generally reused or treated before discharged as waste. As a result of the treatment the B.O.D. load of discharged paper mill white water is generally fairly well controlled.

Pulp mill wastes, on the other hand, including blow-pit liquor, wash and bleaching liquors are generally very high in dissolved organic matter and B.O.D. In addition the effluents may be either strongly acidic (sulfite) or alkaline (kraft and soda). The dissolved organic matter in these liquors unless removed is very harmful to receiving streams, since it depletes the stream of oxygen through biological decomposition, and in addition may impart considerable color.

Value of B.O.D. for various mills representing reasonably good operation for mills in the eastern states are given below.

source of waste	population equiv./ton of product	lbs. of suspended solids/ton of product
sulfite pulp mill	3,000-4,000	35-45
kraft or soda pulp mill	200-300	40-60
groundwood	100-130	70-85
deinking plant	200-800	600-1,100
rag plant	800-850	250-300
bleaching plant	100-200	35-45
paper mill	10-100	100-125

Spent sulfite liquor presents a greater pollution problem than sulfate or soda mill waste because of the high biochemical oxygen demand. The principal offending substances are dissolved materials such as carbohydrates, organic salts, and lignosulfonic acids. Although sugars comprise only 20 per cent of the total solids, they are mainly responsible for the B.O.D. Lignosulfonic acids are not particularly harmful since they undergo relatively little decomposition in mill streams. Even when B.O.D. is not a serious problem, sulfite spent liquor can result in excess slime growth in the receiving water body. Spent sulfite liquor is of little use in formulating by-products although some of the liquors can be reused to a certain extent.

Soda and sulfate pulp mill wastes have a relatively low oxygen demand because most of the soluble organic material in the waste liquor is burned in the alkali recovery process. With good operation the total pulp and paper mill waste from a kraft mill can be reduced to a fairly low B.O.D. per ton. The weak wash liquors from the sulfate and soda pulp mills which escape the recovery process have a toxic effect on fish and plankton because of the chemicals in the liquor mainly sulfides and mercaptans. With an efficient chemical recovery system, the concentration of these materials are so low by the time the wastes are diluted at the receiving stream that there is little hazard to fish or other aquatic life.

Mechanical pulp mills have basically the same problems as that of a paper mill. The white water that comprises the effluent from a mechanical pulp mill has the same effect of turbidity and discoloration as the paper mill. Likewise, the amount of dissolved solids is small because the pulp is not produced chemically but rather manually. Through reusing of the wash water much of the fiber in the waste can be utilized, thus reducing the B.O.D. and the amount of total pollutants added to the stream.

CHAPTER III

INDUSTRIAL WATER POLLUTION CONTROL MEASURES

The purpose of this chapter is to summarize and describe the various measures that traditionally have been used or are currently available for controlling industrial water pollution. The first section of the chapter describes the standard processing techniques typically used by the industry for purifying water. The second section is an historical summary of water pollution control legislation. The final two sections deal with more recently emerging sources of control - section three with the growing influence of public opinion, and section four with the various forces within the industry and even within the firm that exert different amounts of control. These two final sections are concerned with several common points: the awakening of industry's awareness for the need of action, joint efforts of control, and a more realistic approach to their public responsibilities.

Industrial Processing Techniques

Purifying and cleaning water has been a problem for a great number of years. Man has had the technical know-how necessary to stop at least some forms of pollution for a long time. Unfortunately man has not always thought it necessary to apply all his knowledge to some problems; in fact man does not always recognize the existence of the problem.

Man has used his technical know-how to develop some interesting and some quite effective means of combating industrial water pollution. The different methods available for reducing pollution can be broken down into those consisting of pretreatment, biological treatment, and tertiary treatment. In this report we will consider mainly methods of pre- and biological treatment.

The pulp and paper industry has a problem that is not unique among heavy users of water for industrial purposes. More often than not the pulp or paper mill must treat the water before it enters the processes. A sequence of treatment processes is often employed to make the water clean or pure enough for process use.[1] These include: aeration, flocculation, sedimentation, filtration, softening, and disinfection.[2] These processes can also be used in treating waste water in conjuction with biological treatment.

<u>Pre-treatment</u>.

1. Aeration. Water may be aerated by spraying or bubbling so that air can get at it, or by permitting it to trickle over trays where the water is dispersed into thin films. Aeration is desirable because: 1) it allows such gases as hydrogen sulfide and carbon disulfide to escape

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1. Libby, p. 144-149.

2. Much of the material in this section unless otherwise noted is from Casey, p. 842-853.

from the water; 2) it increases the absorption of oxygen thereby oxidizing the soluble ferrous iron, which if not removed here would impart a yellow color on the finished paper, to the insoluble ferric state; 3) it improves the odor and taste of the water.

2. flocculation. Much of the suspended matter in raw water is colloidally dispersed and cannot be readily removed by sedimentation or filtration. To overcome this difficulty, the water is first treated with flocculating agents. This treatment flocculates the finely divided material into larger agglomerates, which can be removed readily by sedimentation or filtration. Flocculation constitutes one of the most important processes in waste treatment. In addition to removing much of the organic coloring matter and the matter causing turbidity, flocculation also helps to remove any taste and odor-producing substances which may be present. Flocculation helps to remove iron if it is present in the organic or colloidal form.

3. sedimentation. If the water is of the type easily settled out, a single sedimentation may be all the treatment which is required. However, in most cases the water must undergo flocculation beforehand to increase the amount of sedimentation. After the water has been treated with the flocculating agent, it is allowed to stand quietly for 30 minutes to 4 hours in order to settle out the floc which is formed.

4. filtration. This process involves the removal of flocculated and suspended material so as to produce a clear and sparkling water. Either gravity or pressure filtration can be used. Filtration usually follows flocculation and sedimentation which removes the coarsely suspended material.

Sand beds are the most common filtering media. These filters will not retain any material which is coloidally dispersed. The function of the sand is to retain gelatinous floc which serves as the real filtering media.

Other filtering media may be used in place of sand. A specially graded and washed anthracite coal is sometimes used when mixed with gravel. Activated carbon is sometimes used when it is necessary to remove all organic substances producing odor and color from the water. Carbon in this form is effective because it selectively adsorbs the substances responsible for the taste, odor, and color.

5. softening. Softening of water[3] involves a chemical treatment of the water to reduce or remove hardness. Hardness is a term used in reference to water containing dissolved salts which have a soap-destroying power. Calcium and magnesium are the most common salts in this group, but iron, aluminum, and mangenese are also responsible for hardness. Softening should not be confused with flocculation, since flocculation is concerned with the removal of coloidally

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3. Libby, p. 149-151.

dispersed material, whereas softening is concerned with the removal of dissolved salts. The two principle methods of removing hardness-producing salts are the precipitation and ion exchange.

6. disinfection. The disinfection of water is a very important part of water treatment before process use. By treating the water in this way most of the bacteria that could foul the system are destroyed.

All of the above methods are often employed to purify water prior to entering the pulping or paper making process. The wastes from the pulping and paper mills can often be partially clarified by utilizing some of the treatment methods mentioned. Especially important in waste treatment are sedimentation, flocculation, and filtration. To date these are the only methods used to any extent. In general these processes can be carried out on the waste waters in a manner similar to the treatment of raw water.

The difference is found in the greater amount of solid matter contained in the waste water. Consequently a greater amount of treatment is required. Conventional methods of coagulation and sedimentation do not greatly reduce B.O.D. of waste water because most of the oxygen demand is due to soluble matter in the water.[4] Most of the methods used to reduce B.O.D. are classified as biological treatment procedures. Included as general methods of reducing B.O.D. are:

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4. Casey, p 872-875.

bio-oxidation, trickling filtration, and anaerobic digestion.

Biological treatment.

1. bio-oxidation (activated sludge). In this process the mill effluent may be: 1) settled in a primary settler to remove suspended solids, 2) seeded with sewage plant sludge to introduce the required microorganisms, 3) treated with air needed by the bacteria that will now slowly feed upon the dissolved or soluble material and held in an aerated detention tank, and 4) settled to remove the sludge from the treated effluent. The treated effluent can be discharged and a portion of the activated sludge can be returned at the head of the process for seeding the incoming mill effluent.[5]

2. trickling filtration. Another suggested method of handling mill waste is in trickling filters by which the waste water is trickled over a large surface consisting of a bed of rock or other porous material. Microbiological growth develops on the surface. After passing over the trickling filter, the material is charged to a settling tank where the solids formed in the process are settled out. It is possible in this way to substantially lower the oxygen demand of the waste water. However, the method is not practical on volumes encountered from even a small pulp or paper mill due to the nature of some of the wastes.[6]

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5. A. L. Landesman, Paper Trade Journal, Vol. 141, January 21, 1957, p. 25-27.

6. Edward B. Besselievre, The Treatment of Industrial Wastes, McGraw-Hill, New York, 1969, p. 213-218.

3. anaerobic digestion. At higher temperatures of 33 to 37°C. (91 to 99°F.) anaerobic digestion has shown promise on an experimental scale as a method of treating strong wastes. Use of sulfite waste liquor for yeast and mold production has not yet proved to be an economical means of reducing B.O.D. However, a recent anaerobic treatment process similar to the trickling filter but using an anaerobic filter has proved more successful.[7]

Some Economies and Advances

Returning to the idea of the treatment of water prior to its use in the process, it inherently makes sense that if the mill is going to spend money to clean the water, it should not simply throw it away. One good reason is that by saving the spent liquors and process waters in save-alls, tremendous cost reductions can be realized. Depending on the process, oftentimes valuable fiber can be recovered and returned to the system. Chemicals like activated carbon can also be regenerated and either used in process or sold commercially. One overriding advantage to the use of save-alls is that in cleaning the spent liquors and recovering valuable chemicals the mill also reduces the amount of "fresh" water they have to treat. Often the content of spent liquors is better known than the contents of water obtained from an adjacent

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7. <u>ibid.</u>

stream. So besides reducing the level of pollutants, the firm also reduces its water demand by the use of save-alls.

Several technological advances have been made in the actual processes of making pulp and paper that also reduce water pollution. The sulfate process developed earlier finally achieved well-deserved popularity in the thirties reducing the importance of the sulfite process.[8] The sulfate (kraft) process was and still is no cure to water pollution but effluents from a kraft mill are more useful and adaptable than those from a sulfite mill. The development of a "quick cook" in the sulfate process reduced the cooking time and hence the steam requirement from 10-12 hours to 4-6 hours.[9] The semi-chemical process also became popular in the forties, but this, too, is no answer to all the ills of industrial water pollution.

Government's Effect

Current technology is adequate to clean up our waterways. In like manner so is the current legislation now on our books sufficient to safeguard a liveable environment. The trouble is that these laws have not until recently been effectively enforced.

Federal legislation. As far back as 1899 the Rivers and

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8. Britt, p. 128.

9. Comparison between Eldridge (1942) and Britt (1970).

Harbors Act prohibited dumping of waste and sewage that impeded navigation into harbors and rivers. Now after 72 years the law has been revived.

The Rivers and Harbors Act required that a firm apply for and receive a permit from the Army Corps of Engineers before dumping effluents into any navigable water.[10] The original law exempted waste dumped by a municipality through its sewer system. The Act had the necessary teeth since as interpreted by the U. S. Supreme Court it prohibited all direct and virtually all indirect discharge of anything but practically pure, unheated water into waterways. The law was not enforced, however, until fairly recently.

Human health factors in water pollution[11] were brought to light by the Public Health Service Act of 1912 which contained provisions authorizing investigations of water pollution related to the diseases and impairments of man. The Oil Pollution Act of 1924 was enacted to control oil discharges in coastal waters damaging to acquatic life, harbors and docks, and recreational facilities.

Efforts to obtain comprehensive Federal water pollution control legislation continued, and almost successfully passed in 1936, 1938, and 1940. These efforts were interrupted by

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10. Material taken from lecture notes in a course entitled "Water Institutions and Policies," CE 365/665, taught at the University of Massachusetts, Amherst, February 16, 1972.

11. Frank Graham Jr., Disaster by Default, M. Evans and Co., New York, 1966, p. 46-51.

World War II, but were renewed in 1947 culminating in the enactment of the Water Pollution Control Act of 1948. This law was admittedly experimental and initially limited to a trial period of 5 years, after which it was to be reviewed and revised on the basis of experience. This 5-year period was extended for an additional 3 years to June 30, 1956.

Comprehensive water pollution control legislation of a permanent nature was finally enacted with the passage and approval of the Federal Water Pollution Control Act of 1956. The 1956 Act[12] extended and strengthened the 1948 law and was administered by the Surgeon General of the Public Health Service. The law provided for grants rather than loans to be made to eligable municipalities. The Federal government was given expanded authority to enforce the law for all water that crossed state lines but as yet had no control over intrastate waters. The procedure for regulation was to give a state a 30 day notice that a conference was to be held, to tell the state at that time that they had 6 months to take remedial action, to determine at the end of 6 months if corrective action was taken, and if not to bring the state before a hearing board to further discuss the situation. This procedure inevitably resulted in prolonged delays of several years. In fact, no case was ever brought to court under this law.

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12. op. cit. "Water Institutions and Policies," CE365/665.

In 1961 Congress passed the Federal Water Pollution Control Act Amendments of 1961. The amendments[13] improved and strengthened the Act by extending the Federal authority to enforce abatement of intrastate as well as interstate pollution. The Act also resulted in increased amounts of Federal assistance to municipalities through grants for construction of treatment plants. The 1961 Act also provided for the inclusion of storage in Federal multipurpose reservoirs to supplement low flows for water quality improvement.

The law was once again amended in 1965. The 1965 Water Quality Act was highly significant because it broadened Federal jurisdiction through a provision requiring the establishment of standards of quality for all interstate waters. The states were required to set such standards (to be approved by the Secretary of Health, Education, and Welfare) by June 30, 1967, or face the imposition of Federal standards. Also a new agency - the Federal Water Pollution Control Administration (F.W.P.C.A.) - was created to remove the program from the program from the U. S. Public Health Service and place it directly under the control of the Secretary of Health, Education, and Welfare. This represented an effort to broaden and improve the status of the Federal water quality effort.

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13. Most of the material in the following section is taken from U. S. Environmental Protection Agency, Federal Water Pollution Control Act, Washington, D.C., September, 1971.

The Clean Water Restoration Act of 1966 further increased the Federal subsidies available for municipal waste treatment facilities. If certain conditions are favorably met, the Federal share can rise to as high as 55 per cent of the capital costs.

Yet another piece of legislation dealing with water pollution is the Water Quality Improvement Act of 1970. The Act allows for increased subsidies and authorizations for a wide variety of activities ranging from training programs to construction costs. Dumping of pollutants such as oil and sewage from vessels is now under control of the Federal government. Especially important for pulp and paper manufacturers are two sections of the act. One deals with defining control of hazardous polluting substances and puts the finger on polluters of all types by making them responsible for removal of the pollutants. The other section along with the National Environmnetal Protection Act of 1969 requires impact statements of the damage to be caused by, say, a mill to the receiving water. The impact statement is to accompany the application for a permit to pollute required under the 1899 Act.

Other Federal measures. The legislation discussed is at the disposal of the Federal government to control water pollution. As mentioned, until recently little has been done to enforce these rules and standards, but now there appears to be a trend developing towards applying the acts to at least the heavy polluters.

Other avenues of control or inducement open to the Federal government in their effort to get business to reduce pollution exist. Two of these are in effect now and are involved with more or less economic aspects of reducing pollution. They involve the tax laws.

Business firms are allowed by government to amortize the cost of any capital equipment at an accelerated rate. By doing this the firm is free to utilize the funds from this non-cash expense in other areas.[14] Similarly a business is also allowed a tax incentive of 7 per cent for all new capital equipment including pollution control equipment. For example if a firm installs a waste water treatment system at a cost of $100,000, the government will allow the firm to deduct $7,000 from its income taxes for that year in addition to the full cost of the machine over the useful life of the asset.

These methods are now in effect but several other possible alternatives or additions to these means have been suggested, some more or less advantageous to the firm while others are not as advantageous. One of the more favorable methods entails the government guaranteeing to loan business money for the purpose of installing pollution control equipment. Another suggestion is to tax polluters and apply the

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14. see Charles T. Horngren, Cost Accounting, A Managerial Emphasis, Prentice-Hall, Englewood Cliffs, 1967, p. 490-492.

tax collected to advancing regional water pollution control programs.

State vs. local vs. Federal. Up to this point we have been dealing with government strictly on the national level. This is not to imply that states or municipalities have either no power in dealing with pollution nor that laws are identical to Federal laws. The simple truth is that quite often local laws are in contrast to Federal laws. An example is the State of Vermont and the standards the people there have set. According to Federal standards it could be perfectly legitimate to operate a mill in Vermont as long as the mill maintains certain levels of B.O.D. or pollution control. However, it is quite possible that this mill could not meet the strict standards of Vermont but yet could still be within the standards of the Federal government. In such a case Vermont would not allow the mill to operate.

Several problems are inherent in a system where each level of government has some control but no one has all the control. The most obvious question of a mill owner is, "Whose standards do I obey?" The answer is rather poor in that he must obey them all or face being prosecuted for not obeying. Actually, less confusion exists than is indicated by the last sentences, but the point is well made that confusion over jurisdiction and responsibility often results in a neglected environment. In practice state statutes include a plan for attaining standards. These standards must be approved by the Federal government, and then the standards apply for both state and Federal governments.

Another failure in this type of system can best be explained by example. Assume two identical paper mills, one in upper New York on Lake Champlain, the other on a comparatively unpolluted river in Nevada. According to state standards each would be allowed to emit different amounts of effluent since the impact of the pollution of each mill would be different on the respective bodies of water. The river near the mill in Nevada would be able to assimilate the waste much easier than Lake Champlain. So by reason of geography and geography alone, the mill in Nevada can let more of its effluent go comparatively untreated, thus cutting costs of pollution control and increasing profits.

One way of possibly eliminating this situatin is to require each mill to dump its effluent into municipal sewer systems if they exist. Instead of paying to build their own treatment plant, the mills could now contribute to a town-owned treatment plant that could probably treat the joint waste more effectively and effeciently than either could separately. This suggestion of course assumes that a municipal sewer system is readily available. This is not always the case, since it is generally estimated that about one-third of all municipalities dump raw sewage into nearby bodies of water.

Complications again arise since the Environmental Protection Agency requires that industry is not to receive a grant even when it uses the municipal sewer. Industry is required to pay a charge that includes amortization of a part of the capital costs. When an industry's waste discharge represents a substantial part of the total waste flow in a municipality's sewer system, then industry is required to pay a charge that includes operation costs plus a fair portion of the amortization costs.

Public Opinion's Effect

Technology and government have not been the only factors that influenced pollution levels over the years. The public has exerted power over industry in many and varying ways but not in the way that is most effective - through the market. The market approach to pollution abatement is not a favorite means of solving the problem. Recently, however, several possibilities for incorporating pollution costs into prices were advanced. This approach through the market will be further explored later in the report.

Given that the public has had little or no control over industry through the market, how then did the public exert any influence? One of the ways the public helped to control industrial water pollution was by forming groups or coalitions against pollution. The effect of this type of action can be seen more readily in recent times when groups such as the Council on Economic Priorities form. This particular group recently published a report on a study of twenty-four of the nations largest paper companies. For the most part the report condemns many of the major companies and states that the job the companies are doing to fight pollution is largely inadequate.[15] It is interesting to note that a spokesman for St. Regis Paper Co., cited by the study as one of the worst polluters, said the company now plans capital expenditures of $65 to $70 million over the next three years on pollution control at its primary mills. This amount is about the same as the Council suggested and is up from earlier estimated expenditures of $36 million.[16]

Perhaps the best praise for the Council and sound logic for their survey appeared in the Nation as an editorial on January 4, 1971, when it was stated:

> "Surveys of this kind provide a new technique for public-spirited citizens, mutual funds, etc. - everybody with funds to invest - to work for the public good. Other things being equal, it is obviously in the public interest to reward the conscientiousness by investing in their securities and to punish those who are exclusively profit-minded. This may be sound financial policy even if the stock market does not currently put the culprits at a disadvantage. Companies which persist in polluting air and water face a dim future. They are like a person who is sick without knowing it, or refuses to pay attention to his disease.

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15. Council on Economic Priorities, Paper Profits: Pollution in the Pulp and Paper Industry, Vol. I, January, 1971, p. 12.

16. "Papermakers Assailed over Pollution-Control by Evaluation Group," Wall Street Journal, December 17, 1970, p. 3.

> It will hurt him soon enough.... Aside from civil obligations, the intelligent businessman does not wait until he sees the writing on the wall."

Another way in which the public can gain control over a water polluting firm is to set up regulation and licensing bureaus requiring business to obtain permission to dump effluents into either the local stream or sewer system. In some areas where the bureau is made up entirely of members of the local community this is an effective way of controlling pollution. This can be demonstrated from the increasing amounts of money business is putting into public relations. Companies that do a good job of pollution control find it increasingly necessary to let the public know about it. Georgia-Pacific, a typical example of one of the nations largest paper manufacturers spent approximately $30 million to convince the townspeople of Eureka, Calif. that its newly proposed pulp mill would not pollute the air or water.[17] Georgia-Pacific was forced to do this in order to obtain an operating permit from the community.

One basic weakness to the permit bureau approach is that all too often the people on the committees of the bureau are basically ignorant of the technology involved in nearby mills or firms. In an effort to circumvent this problem the logical although not realistic approach is to place knowled-

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17. "Sounding Off on a Job Well-Done," Chemical Week, Vol. 97, December 4, 1965, p. 35-36.

gable persons on the committee. Obviously the best-informed people are those who work for the mill in question, but there is almost no way a committee member is going to vote against himself and his company.

It is interesting to note, however, just how far some firms will go in their efforts to convince the public of how ecology-minded they are. To illustrate, Scott Paper in Philadelphia provides an excellent example.[18] Scott is considering marketing a line of "environmental products" made from reclaimed and recycled paper rather than from timber. They hope the consumer is environmentally minded enough to want to use a product that does not require felling a tree. Scott is considering this move in spite of the fact that they might lose profits. Due to the fact that Scott owns roughly three million acres of forests, and the company receives a tax credit each time it cuts lumber.

One last means the citizen has to fight pollution is to elect or at least support political candidates at all levels of government who are concerned with the environment. In this way the people can be assured that their right to live in a community free from pollution is at least being defended and not sold down the river.

To put it plainly, though, the consumer or the public

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18. "Paper's New Bag: Ecology," Sales Management, Vol. 104, May 1, 1970, p. 62-63.

have little or no real control over the corporation except through government and the coalitions mentioned. Even this control is limited and not guaranteed to be effective. Recently legislation was passed in Michigan that makes a provision for a private citizen to easily file suit against a polluting firm.

Intra-Industry Co-operation

Over the years industry has become increasingly more interested in joint efforts to solve pollution problems. Pollution is realized by industry to be everyone's problem, not just that of the consumer, the government, or industry alone. In an effort to incorporate everyone into the problem several industries in certain areas of the country are joining in a systems approach to water pollution. The following example is given as an illustration of the systems approach:[19]

> "A plan for the establishment of the Maryland Waste Acceptance Service is being prepared for the approval of the state legislature. The agency will, if approved, acquire all existing waste treatment facilities and henceforth be responsible for the collection and treatment, on a reimbursable basis, of all municipal and industrial waste waters."

Another but weaker influence industry exerts is via the stockholder of a firm. The stockholder is in a most interesting position due to his dual roles, that of owner and hopefully profit-maker, and that of consumer. As far as major

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19. Austin H. Montgomery, "Systems Approach to Water Pollution Abatement," Journal of Systems Management, Vol. 22, March, 1971, p. 490-492.

influence, he exerts about the same amount of power in either role. Traditionally in the twenties and thirties the stockholder was viewed as having a fairly large say in the firm as a whole. Today with the increase in conglomerates and the vast diversification of stock in most firms, the shareholder has little say unless he own huge blocks of stock. Such is the case with some mutual funds that are presently concerning themselves with various environmental affairs including water pollution. On the whole, the stockholder has relatively little influence over the management of the mill including on environmental issues.

One other way that industry can reduce pollution is through a public relations approach. Assuming almost all if not all people are willing to reduce pollution, the consumer should be more willing to buy the product that pollutes less or produces less pollution while being produced. This assumption may or may not be so, but I feel most industry takes this as a fairly basic truth. Therefore, the mill that pollutes less or installs more pollution control equipment <u>and</u> tells the public, has a theoretical competitive edge. This idea can boomerang, too. There is little to prevent a firm from "overtelling" the public of its efforts to reduce pollution. Nonetheless, a great deal of anti-pollution effort is spent each year for the sole purpose of improving face with the public.

Obviously many factors have influenced the levels of pollution in this country. We have discussed but four factors in this chapter. In the next chapter we shall look at several others.

CHAPTER IV

POSSIBILITIES FOR WATER CONSERVATION AND ANTI-POLLUTION MEASURES

Up to this point various processes in the pulp and paper industry that pollute water have been examined. It has been determined where pollution occurs in the porcess, and how much pollution is caused by each method. Various methods used and still in use to eliminate some of the polluting substances have also been discussed. And finally it was shown how different segments of society exert influences over a polluting firm. The list of measures that can be employed to reduce pollution has not, however, been exhausted. Many aspects that are basic to the firm such as economic or social considerations of pollution have not been discussed.

In this chapter an attempt shall be made to describe some of the economic and social implications involved in industrial water pollution. An attempt shall be made to describe some possibilities for curbing pollution, many of which now exist, others that are not now in use but are feasible.

Economic and Social Considerations

Inherently it makes sense that a mill will do everything within reason to cut costs in an effort to maximize profits. Clearly though it makes sense that the entire expenditure for pollution abatement equipment cannot be recovered immediately either through sale of by-products or lessening of the water requirements. Thus, expenditures of this nature do not necessarily maximize profits.

In this section we will explore: why business assumes a social responsibility, the relationship between private and social costs, various market mechanisms, the possibility of regional water quality, and finally some interesting economic considerations of pollution.

Social responsibility. Almost as many definitions exist for social responsibility as for water pollution. A rather long but thorough definition follows:[1]

> (Social responsibilities) "mean that businessmen should oversee the operation of an economic system that fulfills the expectations of the public. And this means in turn that the economy's means of production and distribution should enhance total socio-economic welfare. Social responsibility in the final analysis implies a public posture toward society's economic and human resources and a willingness to see that those resources are utilized for broad social ends and not for narrowly circumscribed interest of private persons and firms."

The social responsibility of business can be broken up into two distinct categories.[2] The first is of those responsibilities that are internal to the firm including: employee selection, training, promotion practices; physical

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1. George A Steiner, Business and Society, Random House, New York, 1971, p. 141 as he cites William Frederick, "The Growing Concern Over Business Responsibility," California Management Review, Vol. 2, Summer, 1960, p. 54-61.

2. ibid.

working conditions; and efficient and maximum use of resources. The second is external responsibilities of the firm which include: full employment; price stability; the impact of advertising; and air and water pollution. Of particular note is the maximum and efficient use of resources which we discussed earlier while considering recycling and by-products. Also of note is the fact that water pollution is an external social responsibility. This no doubt comes as a surprise, but we will explore the concept further when dealing with private and social costs.

Why, though, should a mill care about cleaning up the environment and becoming socially responsible? Four reasons might be:[3]

1. Discharge of pollution violates the rights of downstream users and owners.

2. The public more or less expects business to help in dealing with social problems, and business is sensitive to public opinion as we have seen.

3. Business is concerned in their own self-interest for a better environment in which to operate.

4. If business does not assume the socially responsible role, someone else like government might force them to assume the role.

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3. ibid., p. 144-145.

Social costs and private costs. A strictly economic approach to social responsibility would involve an analysis of social costs. Social costs are the external costs of doing business including the cost of production and the cost of maintaining the environment at a stable level. For instance, a mill dumping pollutants into a clear stream incurs two kinds of costs. One is the cost of its operation (private costs); the other is the cost that results from changes to the stream's ecology including destruction of acquatic life and the natural beauty (social costs). To the extent that business does not bear these external costs they must be borne by others.

An illustration of private and social costs is useful in understanding the effects of pollution in a potentially real-life situation. Let us assume there is a stream that is unpolluted - a fairly broad assumption. Let us also assume there are two paper mills roughly twenty miles apart on this stream. The up-stream mill is A; the down-stream mill is C; B is a resort hotel that uses the water for recreation purposes such as swimming, boating, and fishing and is located on the same stream mid-way between A and C.

Initially let us assume that A has pollution abatement equipment that accrues $25,000 of expenses each year. If this equipment renders the water as clean and pure as before A used the water, then obviously the cost of clean water is $25,000 per year. With the equipment present and A assuming the cost of maintaining the equipment, the cost of clean water is $25,000 per year. With the equipment present and A assuming the cost of maintaining the equipment, the cost of clean water for B is free.

Assuming now that B imparts no impurities into the water, the initial cost of the water for C is also free. If C does not have any pollution control equipment, the cost is still free since C has not spent any money at either end to clean up the water. If C does have equipment, then the cost of the clean water is the cost of maintaining the equipment plus depreciation.

Now let us assume that A has no pollution abatement equipment; therefore, A incurs no cost of cleaning up the water. If B is to stay in business, he must now spend $25,000 per year to clean up the water. But why should B have to spend the money to clean up the mess made by A??? If A were socially responsible or forced in some way to assume his full social cost of $25,000 per year for cleaning up the water, B could stay in business. If B goes out of business because he cannot afford to purify the water, C must assume the cost. The point is simple: A polluted the water, the $25,000 per year cost is his social cost of doing business.

Given that the cost of cleaning up the water belongs to A since it is his social cost, how do we get A to pay the cost if he does not feel like being socially responsible? At the present time we have to prove in court that A is polluting. Often this involves telling the nature and extent of his polluting effluents and showing that technology exists to change the situation. This process is naturally costly and lengthy and most often not possible for an individual. In some states now, though, the consumer or the public can directly sue the polluting firm, Michigan for example.

Various market mechanisms. Recently several possible means of putting the cost of pollution into the market price have been suggested. One of these means involves putting the cost of pollution directly into the product. In this way the pollution costs are passed along to the customer just as any other business cost normally is.

To digress for a bit, it should be noted that the consumer or general public is in the long-run going to have to pay the price of pollution - at least to a certain extent.[4] Thus, the consumer is going to have to sacrifice some things like money or goods to reduce pollution. As long as people buy products that pollute or demand goods whose manufacturing process pollutes, the situation will not improve.

Other methods not so dicouraging exist to help incorporate the cost of pollution into the costs realized by the firm. One method in particular hopes to make antipollution

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4. David Rockefeller, "Economic Aspects of Environmental Improvement," Technical Guidance Center Bulletin for Environmental Quality, Vol.3, July-August, 1971, p. 1.

a part of the price-profit incentive system.[5] In simplest terms, this would involve charging a fee for every unit of pollutant discharged, with meters used to determine the amount. There would be an economic incentive to stop or to reduce pollution, possibly backed up with the threat to close down the plant if the meter readings go above a specified level. The paper mill in this case could reduce pollution quite a lot but would be controlled so as not to merely choose to pay rather than to stop polluting.

Problems exist for both methods suggested. In the first method of putting the cost into the product, basic discrimination against the small, marginal firm is present. This type of firm could hardly afford to increase costs and still survive in the light of competition from larger, more stable firms. In the same vein, often this small mill is the mainstay of the town in which it is located. Obviously the people in the town would rather be working than unemployed regardless of pollution levels. Such a situation is often referred to as "environmental unemployment."

To carry forth a plan such as mentioned above would have serious repercussions unless the government intervened. If the Federal government could or would guarantee low-

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5. Edwin L. Dale, "The Economics of Pollution," article in a book compiled by Fred Carvell and Max Tadlock, It's Not Too Late, Glencoe Press, Beverly-Hills, 1971, p. 141.

6. Rockefeller, p. 1.

interest loans to some of these small firms to insure their competitive position, perhaps the plan would work.

The problems with the approach concerning the fee for pollution are easier to understand and interpret. Simply, some firms may find it more economical to pollute and pay the tax than to install pollution abatement equipment or to try in other ways to reduce pollution. The only way such a plan would work is if a systematic approach such as a regional water quality system were applied to the whole area or river basin. Such a system is not as simple as first appears.[7]

Regional water quality system. A regional water quality approach is basically the same as the "systems" approach mentioned earlier in the report.[8] To review briefly, instead of each mill or town being required to purify wastes to certain limits, the mill or town is given an option. The option is to clean the water themselves, or to turn the waste over to the agency that is in charge of and assumes responsibility for the entire river basin. To grant the firm this freedom with the waste material the water quality commission charges the mill an effluent fee that defrays the costs of purifying the un-

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7. It is worthy to note that most suggestions for alleviating pollution involve some sort of punitive measure. Drucker in a recent article comments that punitive measures are effective basically only when the offense is small or the offenders are few. Obviously this is not the case in pollution; hence, most methods excepting tax incentives tend not to be effective.

8. Allen Kneese and Blair Bower, Managing Water Quality: Economics, Technology, and Institutions, John Hopkins Press, Baltimore, 1968, p. 213-253.

treated wastes. This approach is perhaps one of the most perfect from the point of economic theory in that a firm purifies up to the point where it is still profitable to do so. Beyond this point we assume the mill would have to buy a new piece of equipment, for example, and it is cheaper to pay the effluent fee. At any rate, the full social cost of using the water is paid by the mill or town that rightly incurs the cost.

Perhaps an example would be in order to help understand the economics involved. Suppose a mill currently has a 1 million gallon per day flow and a waste treatment plant that can purify the flow at this level but not higher. In order for the firm to increase production and to continue to treat all its waste, the mill would have to build additional treatment facilities. Under the regional approach the mill could transfer the excess waste to the regional treatment plant, thus incurring the cost of the effluent fee but still saving money by not having to build the new treatment plant at the mill.

This approach is more feasible from the following points of view: For each mill to buy and operate a complete treatment plant does not guarantee maximizing available resources. In fact certain economics of scale are present. To build a plant of, say, 1 million gallon per day capacity vs. a plant of 2 million gallons per day capacity is not that much cheaper. Not only are the costs of building the facilities of minimal difference but the costs of maintaining and operating the plants are also comparatively similar.

Such a system has been in use in the Ruhr in Germany for more than half a century and appears to be most successful in its efforts. Not only is the full cost of the pollution internalized, but it is done so in a most economical manner. In the Unites States regional water quality management systems that incorporate the full range of alternatives available in the Ruhr are still in the planning stage. The basic ideas are sound, but it is not always easy to get everyone involved to agree to such items as financing, planning, and the operation of the facilities. These problems become especially hard to judge in light of no clear cost-benefit information. Nevertheless several such regional systems approaches are now in operation in the United States.

Zero growth - yes or no? Although such a system has obvious merit some say that the root of the problem lies in the fact that we as a country are growing too fast for our own good. Some people in fact go so far as to state that we should have zero growth, that is, maintain the economy at the present level. This theory is refuted by Edwin Dale in his approach which involves three laws: 1) the law of economic growth, 2) the law of compound interest, and 3) the law of the mix between public and private spending.[9]

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9. Dale, p. 134-142.

The first law states that productivity has risen and will continue to rise between 2 and 3 per cent a year for more than a century. The increase in productivity coupled with the fact that the work force for the next 20 years is already born and intends to work means quite simply more output in terms of power, smoke, cans, bottles, papers, and steel produced. The result is more pollution.

The second, the law of compound interest, explains that the population, productivity, and hence pollution grow at a geometric rate. To put it another way from 1944 to 1957, a period of 13 years, the economy in terms of GNP grew by $100 billion. From 1957 to 1970, a period of 13 years, the GNP grew by $300 billion. Another dizzying way of putting it is that the real output of goods and services in the U. S. has grown as much since 1950 as it grew in the entire period from the landing of the Pilgrims in 1620 to 1950.

The third, the law of the mix between public and private spending states that no matter what the mix between public and private spending the result is the same. Assume we want government to reduce pollution, which necessarily means an increase in taxes. Given that we feel obligated at any cost to reduce pollution, we do not mind the increase. So the government spends the money to reduce pollution. Sewage plants are built. They need steel, they need electric power, they need paperwork, they need workers. The workers get paid, they consume, and they pollute. A shifting in our national income or production between "public goods" and "private goods" hardly changes the environment problem at all because it does little or nothing to reduce total spending or output in the economy.

Reducing total output has ramifications far beyond those that first meet the eye. In economically depressed areas where the first concern, quite understandably, is to generate additional productive capacity to provide more employment and a higher tax base, this plan is hardly popular.

Thus it is obvious that these three laws are far from encouraging since they offer only despair, not hope. But this does not mean mankind is destined to live in a polluted swamp called Earth. He can change. He does not have to pollute the land. How much effort man puts into reducing pollution simply boils down to how badly he wants to survive.

Conserving Water by Recycling and Reusing

Man has several alternative choices in his quest for clean water. In addition to those choices already discussed man can conserve and utilize the water to its fullest extent by a carefully designed program of recycling and reusing[10] the various waste waters from a mill.

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10. Adistinction is made between recycling and reusing. Recycling is reapplying the same resource to the same process over and over, whereas reusing is reapplying the resource to a different purpose.

The paper industry requires water for three basic purposes: 1) steam generation; 2) cooling; and 3) processing. By purifying the water via the various treatment processes discussed in the previous chapter there is no reason why the mill could not theoretically keep using the same water over and over again _ad infinitum_ except for some make-up water. Concerning the treatment of the water, though, one will recall that more often than not the mill is required to purify incoming water before it is used in process. This practice quite simply can be rather costly depending of cource on the nature of the incoming water. To put it a different way the mill has invested in clean water. Once the mill uses the water for its processes it often just dumps the effluent into a nearby stream. Prior to dumping the mill is almost always required to again clean the water to a certain extent. Thus, the mill again invests in cleaning up water but this time merely to throw its investment down the drain, so to speak. One should be aware that this investment has no returns in the normal context of the word, but rather represents an obligation on the part of the mill to the downstream users of water.

Basically the purpose of this section is to explore how the principles of water recycling and reusing can be and in some cases are being applied as water conservation measures by the pulp and paper industry. The basic premise here is that the mill must clean the water at the beginning and end of the process, so why not utilize the investment to its fullest extent by reusing and recycling.[11]

Three broad systems and methods of water management exist that are utilized or could be utilized by the industry. The methods are known as : the once-through method, the multiple use method, and the recycle-reuse method. These are explained below and illustrated schematically using a hypothetical water demand of 15 units in the ratio of 1:10:4 for steam generation, cooling, and processing.[12]

The once-through system. The once-through system makes no attempt to recycle or reuse the water. Any treatment of the waste is complicated by mixing of wastes from the various processes as so often happens in a system such as this.

A firm, and there are many, that uses the once-through system must necessarily incur a tremendous cost in treating the incoming water. In addition the waste generated from the mill is dispersed in a very large amount of water thereby making effluent treatment all the more difficult.

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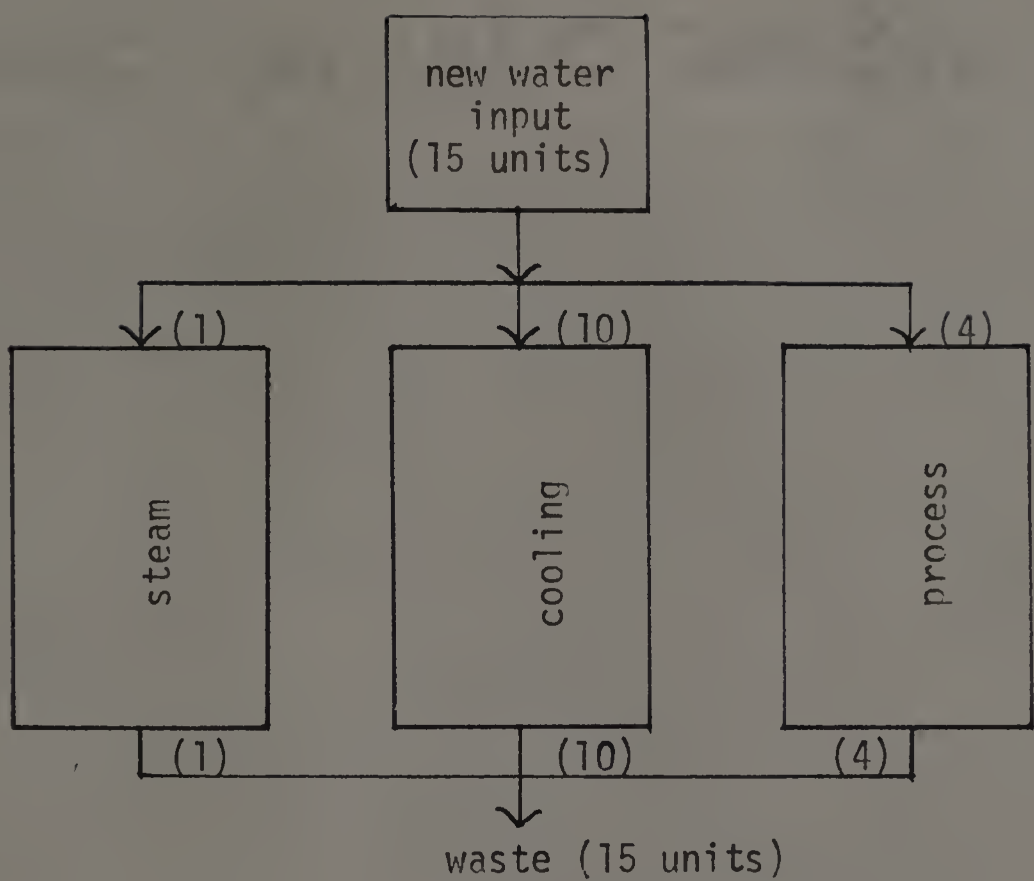
11. To a certain extent this is done, and the resultant cost savings is often significant. Not all mills even attempt to employ this method. Some mills are old, and the cost of installing new equipment would put them out of business even with the cost savings. Other mills utilize recycling facilities to a limited extent, perhaps not obtaining the maximum possible results.

12. Rey, Lacy, and Cywin. "Industrial Water Reuse: Future Pollution Solution," Environmental Science and Technology, Vol. 5, September, 1971, p. 760-765.



Once-Through Diagram[13]

Multiple-use system. The multiple-use or simply the reuse system of water is based on the idea of diverting spent processing water for reuse in the cooling process, and spent cooling water for reuse in the steam generation process.

The advantage of the multiple-use system is that 10 units of water are doing the work of 15 units - a theoretical reduction in new water requirements of 33 1/3 per cent. This naturally also reduces the amount of water which must be pretreated and therefore reduces the cost accordingly. One other advantage is that the waste is now concentrated in only 10 units instead of 15, thus making it easier to treat.

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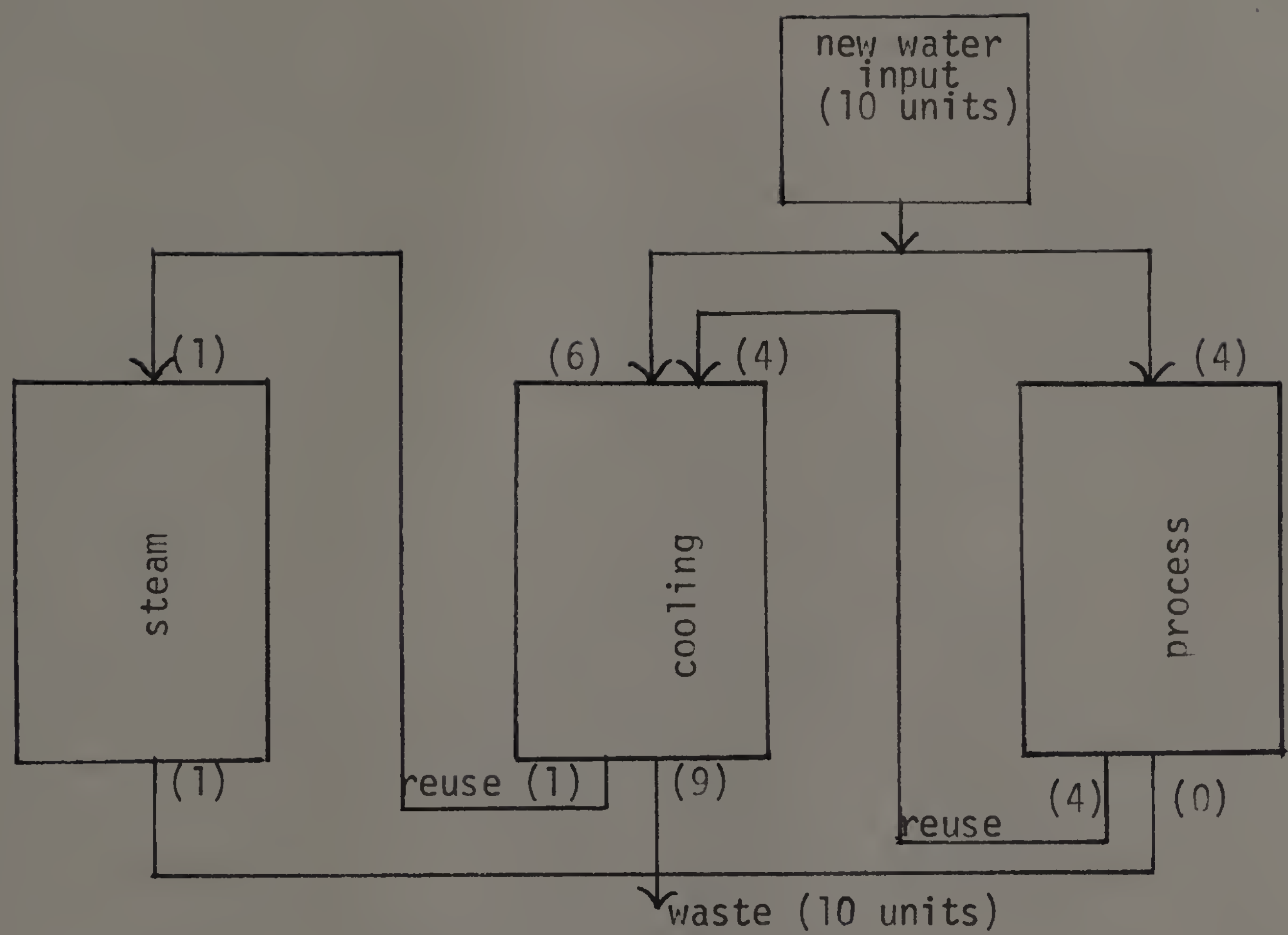
13. ibid.



Multiple-Use Diagram[14]

Recycle-reuse system. The recycle-reuse system is the optimal solution to the recycling problem. In this system 1 unit of water will do the work of 15 units of water by continually being recycled and reused until all requirements are met.

The advantage of the recycle-reuse system is that 1 unit of water is doing the work of 15 units - a theoretical reduction in new water of 93 1/3 per cent. The costs of cleaning new water are minimal and the waste is very concentrated in the 1 unit instead of 15.

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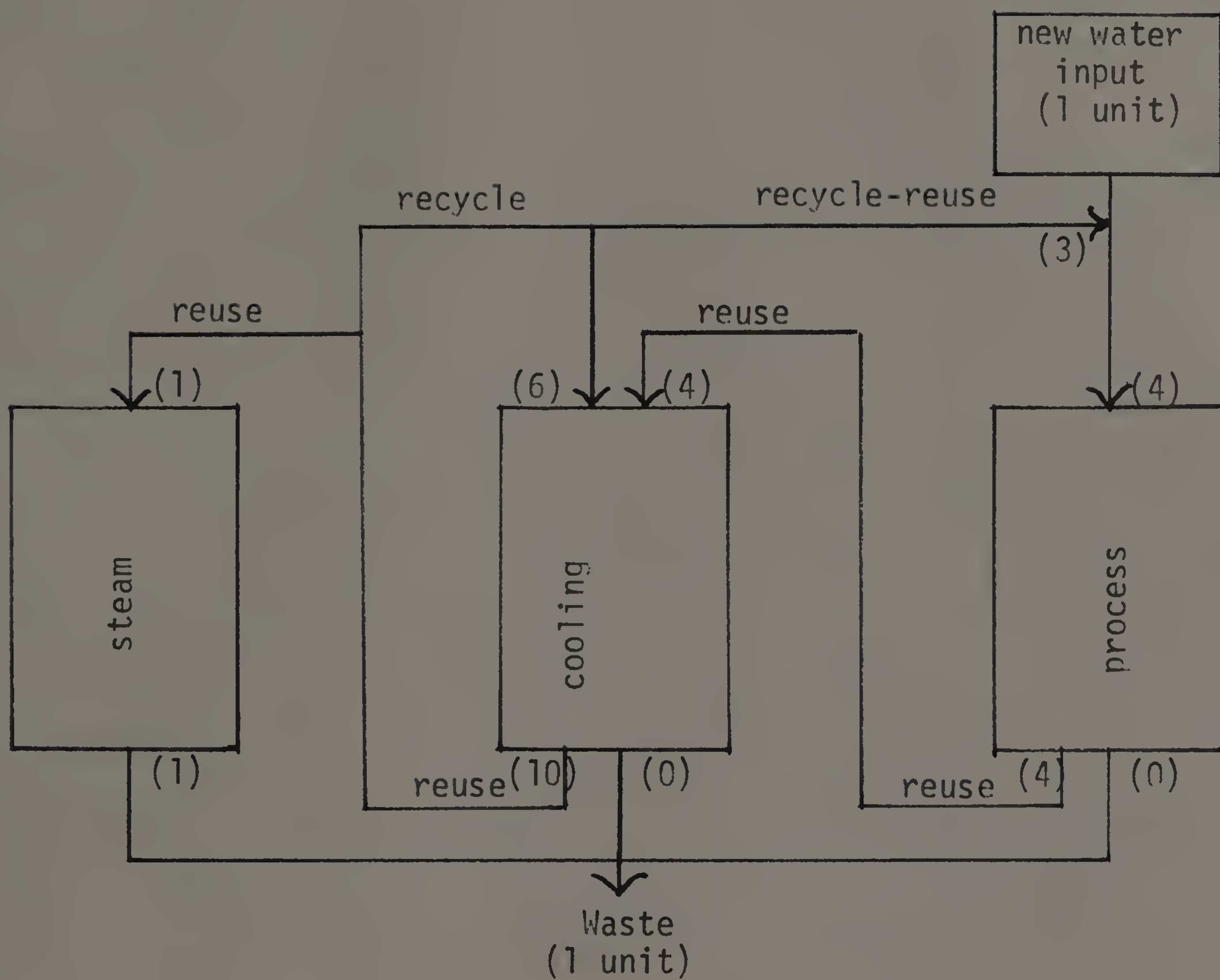
14. ibid.



<u>Recycle-Reuse Diagram</u>[15]

The diagram on the next page shows how a typical mill in very simplified form could employ the recycle-reuse method. One point needs to be stressed here: several areas in this and the previous diagram are not yet technically possible. The point to be gained from this discussion is that more technology is needed, not less, and that by utilizing a similar system to this both the mill and the eco-system would benefit.

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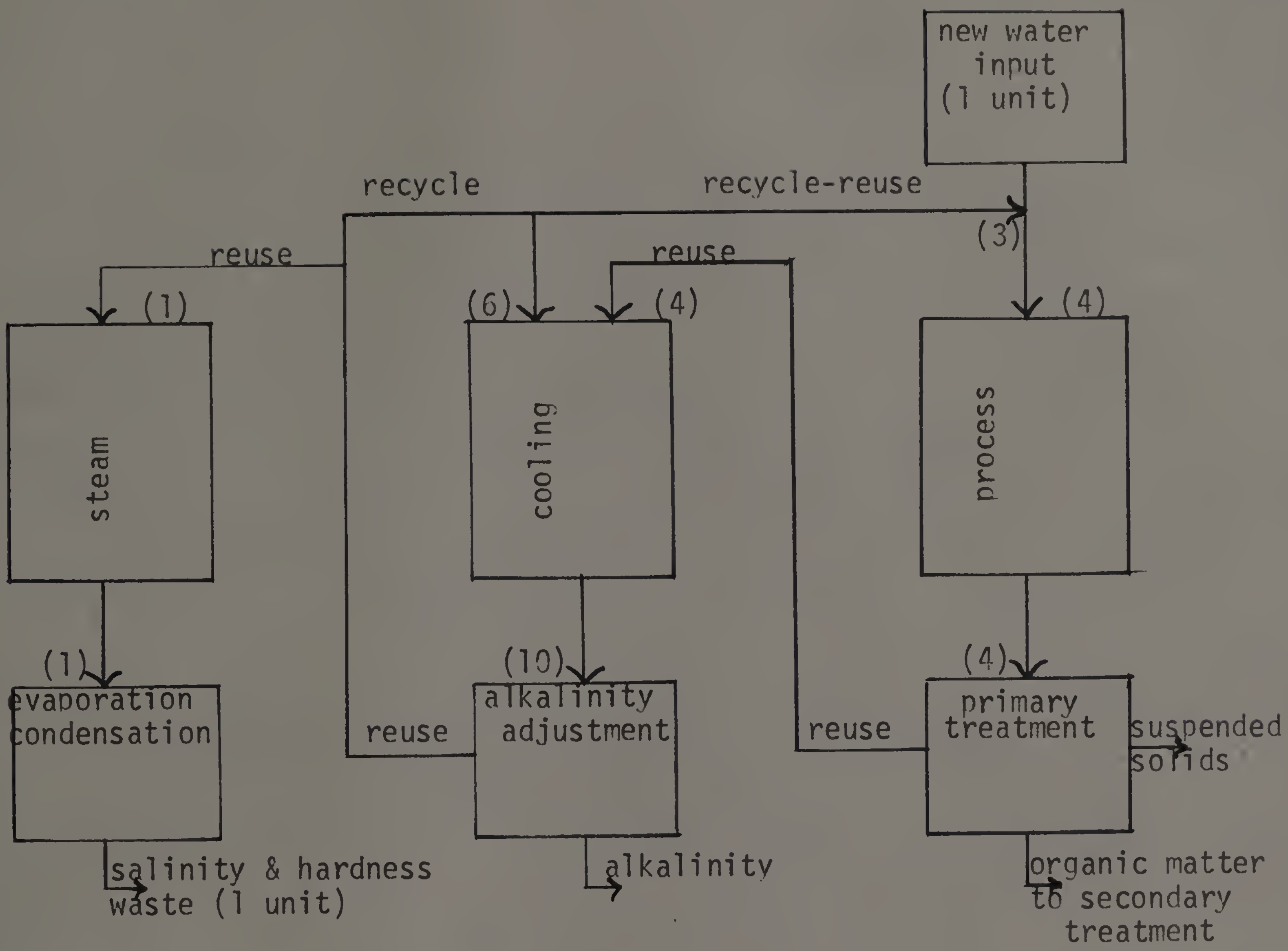
15. <u>ibid.</u>



<u>Recycle-Reuse Treatment System</u>[16]

Recycling Paper

In recent years there has been a rather large trend to recycle or reuse just about anything produced. Paper is no exception to this. The diagram on the next page is a simple illustration showing the pulping operation necessary to convert recycled paper into pulp. The purpose here is to point out that no decrease in polluting material is gained by

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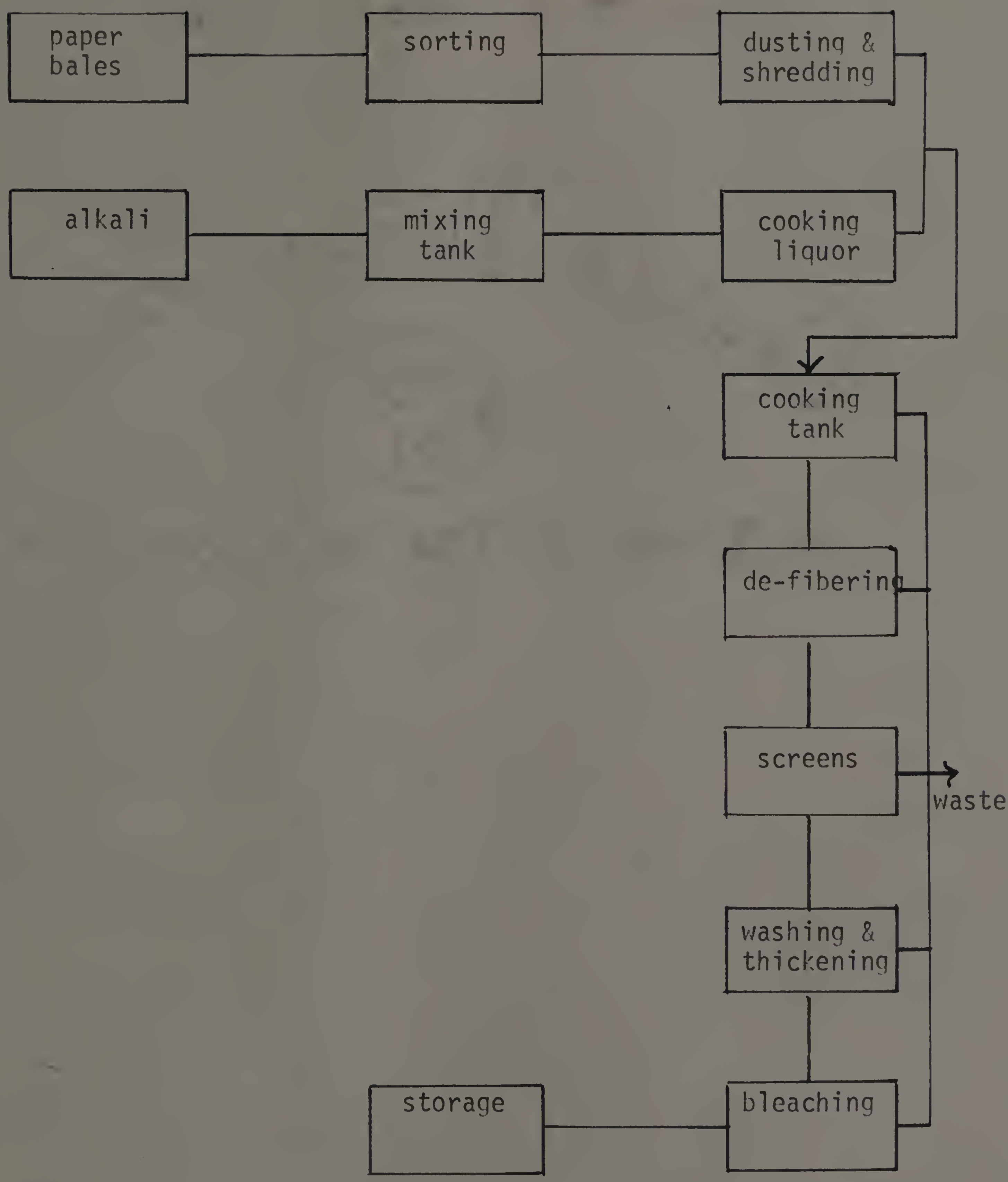
16. <u>ibid.</u>



Flowchart for Pulping of Paper Stock[17]

17. Eldridge, p. 205.

using this process. In fact the effluent contains not only normal pulp mill wastes but the dyes, sizing, and caesin of the old paper. The only real benefit to the environment is not to the receiving stream but to the forest since recycling paper requires less trees to be cut down.

Selling By-Products

For years the pulp and paper industry has been faced with the problem of how to utilize waste liquor produced in the pulping process. As a waste it has presented some serious disposal problems and has led to the use of recovery processes to retain valuable heat and chemicals. These recovery methods have been supplemented in recent years by the development of commercial processes for the production of a wide variety of marketable by-product chemicals from the waste liquors.

Most by-product utilization efforts in the past have been directed at waste sulfite liquor rather than at kraft black liquor. The main reason is that recovery processes for kraft are considerably more advanced than sulfite recovery processes. Few sulfite mills have a recovery system that enable them to recover or recycle any great quantities of chemicals used in the pulping process.

A whole group of products known as Orzon[18] can be

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18. "How Crown-Zellerbach Gets Profits Out of Sulfite and Kraft Mill Liquors," Paper Trade Journal, Vol. 142, September 15, 1958, p. 46-49.

derived from sulfite wastes. These products are useful as binders, dispersants, emulsion stabilizers, and suspending agents. Also from sulfite wastes substances known as conidendrols and conidendrines can be derived. These products are useful in fine chemicals or pharmaceutical manufacture or even in the dye industry.

From kraft mills Crown-Zellerbach makes dimethyl sulfide. Dimethyl sulfide in its pure form is a clear liquid with a sharp, unpleasant odor, a characteristic which makes it valuable as an ingredient in odorants for manufactured and natural gas to detect leaks. Other uses for DMS are as sulfur carriers in agricultural and rubber chemicals and as a base for certain solvents.

Crown-Zellerbach has done so well with these and other by-products that they have set up a Chemical Products Division that converts waste into useful products and does research on developing new products.

A few sulfite pulp mills have constructed full-scale ethyl alcohol plants to convert the wood sugars in their waste liquors. The wood sugars constitutes about 50 per cent of the B.O.D. in sulfite waste liquor. These plants in addition to reducing pollution are operating at a profit.[19] Another and perhaps more promising possibility for waste recovery from

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19. Allen Kneese, The Economics of Regional Water Quality Management, John Hopkins Press, Baltimore, 1964, p. 31.

the sulfite process is the torrula fodder yeast method.[20]

Numerous examples exist of where mills have increased profits as well as reduced pollution by incorporating these and other ideas into their processes. Management should be cognizant of all technological advances that might save the firm money and the environment destruction.

The simple truth to the whole report is that business, the consumer, government, in fact everyone and anyone must become cognizant of pollution and the problems that pollution causes. In this way, and in this way only can mankind ever hope to rid himself and his world of pollution.

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20. For further details see A. N. Hillis and M. E. Wenger, "Process Engineering in Stream Pollution Abatement," Sewage and Industrial Wastes, Vol. 26, February, 1954.

CHAPTER V

SUMMARY AND CONCLUSIONS

During the course of this report a great many points and processes have been discussed. The reader will note that with regard to the various influences of government, society, and industry no one group among themselves can decide effectively how to deal with industrial water pollution let alone as a collective whole. However, the report sheds insight into some of the complex aspects of influence and control. The revitilization of the 1899 Rivers and Harbors Act by the Supreme Court decisions not long ago has made it possible for government to actively participate in a search for cleaner waterways.

In spite of all the effort government has recently put into water pollution control, the problems still remain. While discussing one cause of the problem, the process of producing paper, it was realized that the change in popularity from the sulfite pulping process to the sulfate (kraft) pulping process also brought about reductions in pollutants being added to the water. This is in part due to the recycling of water and the continual reusing of chemicals necessary to economically utilize the kraft process.

Thus even though no one solution to the problem of industrial water pollution in the pulp and paper industry exists, several positive efforts have been made. One of the methods and one that certainly is worth additional research is the technology and the application of recycling and reusing techniques. Nature herself serves as an excellent example of these methods whereby water is continually being reused and revitilized in the self-purification of streams. The report points out that all efforts to recycle are not as fruitful as others. To recycle paper, for example, produces more waste than paper produced from wood. A tradeoff arises since recycling paper reduces the need for cutting down additional trees.

In an effort to make the rivers less polluted and to increase profits at the same time, some mills have engaged in the process of selling by-products. Not only are the waters cleaner and profits bigger, but whole new fields of technology and further research are opened by this measure. One company, in fact, made use of the unpleasant odor associated with certain pulping operations to sucessfully market an odorant that when applied to natural gas makes detection of leaks easier.

Several market approaches to reducing pollution are considered. One such method involves putting the cost of pollution and pollution equipment into the product and passing the cost on to the consummer, but this method hits the small mills the hardest. Often, too, small mills are the mainstay of a town and are not able to absorb cost increases as easily as large mills. These small mills are sometimes competitively forced to shut down resulting in "environmental unemployment."

Perhaps the method with the most promise is that of regional water quality control. In this method a mill maximizes available pollution control equipment at the mill by purifying its waste up to the point where it is still profitable to do so. Beyond this point the mill relinquishes the waste to the regional system that in turn charges the mill a fee for its excess waste. Even though several such systems are currently in operation or in the planning stages in the United States much work needs to be done before a system such as this is put into wide-spread practice.

From this discussion one could conclude that we have at last arrived at the solution to the problem of industrial water pollution. It is true that technology has at its disposal all the available resources necessary to end water pollution. It is also true that government has passed legislation adequate to control water pollution. So it is logical that we should be living in a pollution-free world.

Probably the greatest single factor working against man in his efforts to clean the world is man himself. Business is not to be blamed for all the mess, for as the report points out, business firms in general are anxious to work in an unpolluted environment. On the other hand, it was stated that approximately one-third of all municipalities dump raw sewage into nearby bodies of water.

Man must realize that only by each person doing his share and by working together will the environment ever be healthy. Perhaps we should all more seriously consider John Haynes Holmes when in his book, Sensible Man's View of Religion, he said:[1]

"The life of humanity upon this planet may yet come to an end, and a very terrible end. But I would have you notice that this end is threatened in out time not by anything that the universe may do to us, but only by what man may do to himself."

1. as cited in John Bartlett, Bartlett's Familiar Quotations, Permabooks, New York, 1961, p. 174-Z.

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