THE PULP AND PAPER INDUSTRY: PROCESSES AND POLLUTION

by

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J.A.Villamere

Resource Development Branch
Department of Fisheries and Forestry
Fisheries Service
St. John's, Newfoundland.

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INTRODUCTION

The forests of Newfoundland are one of this provinces most valuable natural resources. The pulp and paper industry is the largest user of this natural resource and is essential to the economy of the province. Pulp and paper mills provide many jobs and the satellite industries that develop to serve the mills and people employed by the mills provide many more jobs. However, the operation of a pulp and paper mill necessitates the production of waste materials, pollutants to be disposed of in the nearest waterway. These mill wastes are harmful to fish life, another valuable natural resource of this province. Yet, for the good of the province and its people, the two industries — the pulp and paper industry and the fishery — must co-exist.

As employees of the Department of Fisheries and Forestry (Fisheries Service), we are aware of at least certain aspects of fish and the fishery. However, we know very little about the pulp and paper industry, an industry with which the fishery must co-exist in this province. In this report, the pulp and paper industry is studied in detail, hopefully, so that Fisheries employees reading this report will have a better understanding of this essential industry. The following topics are discussed in the report:

(1) Manufacturing Process in the Pulp and Paper Industry

(2) Pollution Properties of Pulp and Paper Mill Wastes

(3) Pulp and Paper Mill Waste Disposal in the Marine Environment

(4) Pulp and Paper Mill Waste Treatment

(5) Pulp and Paper Mill Pollution in Newfoundland

THE MANUFACTURING PROCESS

A. Introduction

Wood and all other forms of plant life are composed of fibres known as cellulose and also the materials which bind these fibres together. Cellulose accounts for about one half of the content of the wood. The remainder consists chiefly of a relatively small quantity of hemi-cellulose, chemically more akin to the sugars than to pure cellulose; and a binder known as lignin, of which much has yet to be learned concerning its chemical behavior.

The manufacture of pulp and paper can be divided into three basic operations: wood preparation, pulp making and paper making. Debarking of the wood is common to all wood preparation operations regardless of the pulping method to be employed. Other wood preparation alternatives are used as required.

The purpose of the pulping operation is to reduce the wood to fibre. There are basically two methods of making wood pulp: mechanical and chemical. The first reduces the logs to fibres by pressing them against large grindstones. The result is known as groundwood or mechanical pulp. In chemical pulping, chippers convert the whole wood to chips, which are then cooked at high temperature and under pressure in a chemical liquor. The cooking operation dissolves virtually everything in the wood except the cellulose fibres (the chemical pulp). The yield of chemical pulp is about one half of the weight of the original wood. The chemical pulping techniques most often employed are the kraft, sulfite and soda processes.

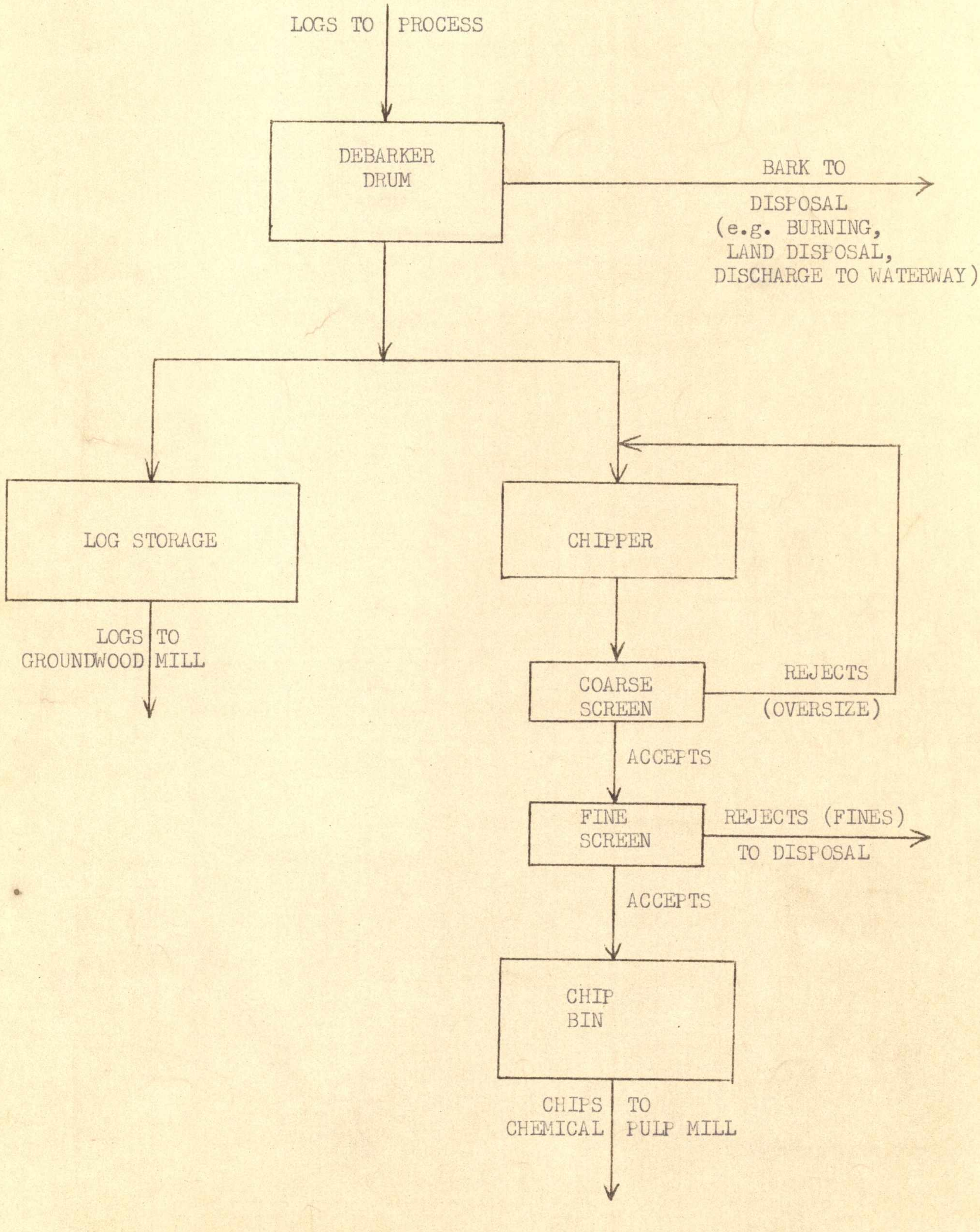
The fundamental phenomenon of papermaking is that cellulose fibres, when wet and in contact with each other, will adhere one to the other as the water is removed. Hence, paper is made by mixing the fibres with water, placing a layer of the mixture on a screen, draining much of the water, and then removing the remaining water by pressure and heat. The fibres mat or felt and become a compact sheet.

B. Wood Processing

The actual process of papermaking begins with the unloading of the wood from the various vehicles used to deliver it to the mill woodyard. Since bark, which occupies 12-25% of the volume of the new wood, has little fibre value, consumes chemicals, and creates dirty pulp, it is usually removed from the pulpwood sticks before these are reduced to chips or ground into a pulp. Hydraulic barking, the stripping off of the bark under high-pressure water jets is one debarking technique in practice today. Water pressure up to 1500 p.s.i. readily removes the bark from all species by impingement. Power consumption is high. Debarking is also accomplished by the use of barking drums, i.e. large revolving steel drums. Barking drums are constructed in sections 12 ft. or more in diameter and up to 22½ ft. long. Normally, two or three sections are used in tandem. The logs are fed into one end of the drum by conveyors and the debarking action takes place as the logs tumble and rub against each other and against the sides of the drum on their way to the opposite end. The loosened bark drops out through spaces or slots and is readily collected and disposed of. The bark may be shredded, pressed to remove excess moisture and then used as fuel in the mill boilers. Bark will provide approximately 9000 B.t.u. per lb. of dry weight. Upon

FIGURE I

WOOD PROCESSING OPERATION



discharge from the barkers, the wood is inspected and any unbarked or partially barked sticks are returned to the barking system.

Logs for chemical pulping are reduced to chips in order to obtain rapid and complete saturation by the cooking liquors. Basically, the chipper consists of a steel casing containing a large rotating steel disk on which adjustable knives are mounted radially. Logs are fed through a spout to impinge against the disk at an angle of about 45° and are reduced to uniform-sized chips, 5/8 to 3/4 in. in a matter of seconds. The knives, themselves, are changed and reground every 8 to 10 hours depending on the condition of the wood and the amount of foreign material it contains.

As they come from the chipper, chips contain up to 2% "fines" and some oversized chips and slivers. Fines include sawdust, fine bark and chips under 1/4 in. or in some cases, 1/8 in. in length. Generally, the larger particles are separated and removed for crushing or rechipping. Several different techniques are employed for the disposal of the fines. To separate acceptable chips from rejects and fines requires a screening system with two vibrating trays mounted one over the other. The top tray has perforations small enough to pass acceptable chips and fines. The second tray, with smaller perforations, catches and retains the acceptable chips while allowing fines to sift through to a chute or to an unperforated tray below for disposal. After the chipping and screening operations, the chips are delivered first to storage bins and then to the digesters by any one of several conveying systems. Chip storage is provided between the wood-preparation system and the digesters to ensure a continuous supply to the digesters and to provide surge capacity where large digesters are loaded intermittently at rapid rates. A simplified flow diagram of the wood preparation operation appears in Figure I of the Appendix.

C. Pulp Manufacture

There are four common types of wood pulp to be considered: mechanical pulp, sulfite pulp, sulfate pulp, and soda pulp. The first is prepared by purely mechanical means, the other three by chemical means. The mechanical pulp contains all of the wood except the bark and that lost during storage and transportation. Chemical pulp, however, is essentially pure cellulose, the unwanted and unstable lignin and the other noncellulose components of the wood having been dissolved away by the treatment. Because of this, chemical pulps are much superior to mechanical (or groundwood pulp) for fine papermaking. However, owing to the special processing required, they are too expensive for the cheaper grades of paper, such as newsprint.

(a) Mechanical Pulp. This process involves no chemical treatment of the pulp whatsoever. The chief woods employed are spruce and balsam, which are of the soft, coniferous species. After arrival at the mill, the wood is slashed and debarked. It is then ready to be ground. The grinding operation takes place in water to remove the heat of friction and to float the fibres away. The grinding is at an acute angle to the length of the blocks in order to furnish longer fibres by tearing rather than by right-angle cutting.

For small tonnages, the "three-pocket" grinder is very widely used. This consists of a central grindstone mounted on a steel shaft and having three chambers or pockets around its periphery. The top of each chamber is surmounted by a hydraulic cylinder which operates a ram whose purpose is to force the blocks against the revolving, usually artificial, stone. These stones are given a suitable type of burr by properly dressing their surface. Cooling and removal of the product are effected by means of a spray of "white water" which is returned to this point from a later step in the process. For larger tonnages, the Roberts and Great Northern grinders are popular, but for the large installations of 200 daily tons or more, either the hydraulic or chain-feed magazine type are preferred. These consist of a large vertical, cylindrical chamber filled to the top with logs. The pressure of the wood on the grindstone at the bottom of the chamber is maintained by the weight of the wood in the magazine.

The pulp and water mixture from the grinders is dropped into a stock sewer below the grinders and is passed along to the sliver screen. Here, the larger material is retained and discarded by the screen, while the fine material falls into the screened stock pit, from where it is pumped to the fine screens. The fines that pass these screens are concentrated in thickeners to give commercial mechanical pulp. The oversized particles from the fine screens are treated in refiners and then returned to the screens again. The water overflow from the thickeners contains about 15 to 20 percent of the original fibres and is the so-called "white water" which is used in grinding and to aid flow in the stock sewer. As the process continues to operate, it is necessary to add fresh water to the system to keep down the temperature; therefore, some of the white water must be removed. Before being sent to waste, this water has the remaining fibres strained from it. The fibre is returned to the thickeners.

The "energy requirements" are all mechanical and consist chiefly of power for grinding. The only chemical change occurring in mechanical pulp is a slight hydration of the cellulose by long contact with water.

The uses of mechanical pulp are for the most part restricted to the cheaper grades of paper and board, where permanency is not required.

The eventual deterioration that occurs in paper made from mechanical pulp is due to chemical decomposition of the noncellulose portions of the wood. In the manufacture of newsprint, cheap manila, wall, tissue, and certain wrapping papers, the mechanical pulp is usually mixed with a small amount of chemical pulp. A flow diagram of the groundwood pulping process appears in Figure II of the Appendix.

(b) Chemical Pulp.

(1) Sulfate or Kraft Process.

"Sulfate process" is perhaps a misnomer, or at least misleading, as it might cause one to suspect that sulfate rather than sulfide is used in the actual cooking. Sodium sulfate is, however, the makeup chemical in the sulfate process, and sodium sulfide is a product of the reduction of the sodium sulfate in the recovery furnace, where the makeup chemical is added.

The sulfate process can be summarized in the following steps:

1. Wood logs are barked in debarkers and chipped in multiknife chippers.

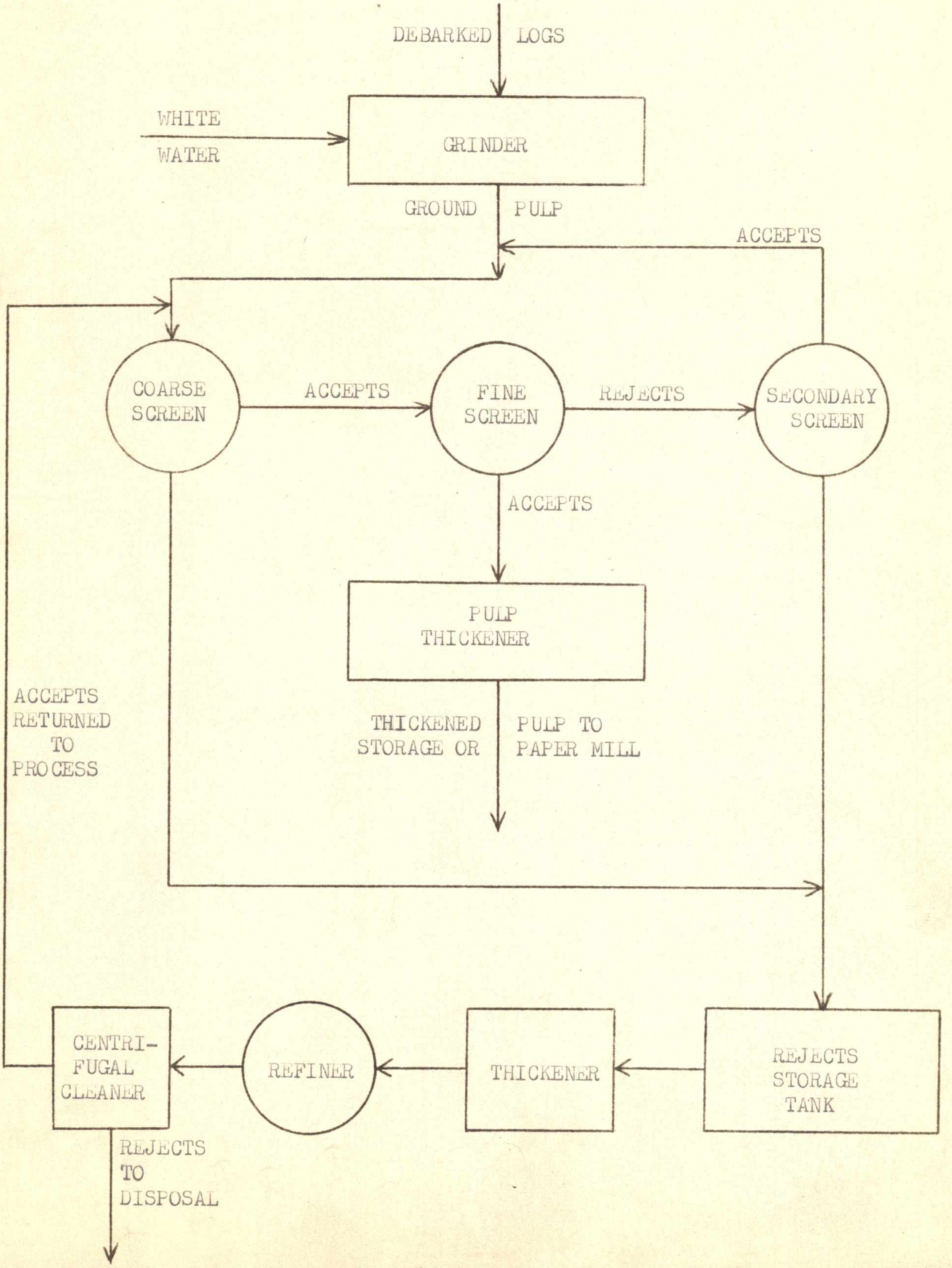
2. These chips are carried by conveyor from the storage silos to the digesters, where the maximum amount of chips are fed into the top of the digester. Cooking liquor is added at this time. The ratio of chips and liquor, along with concentration, moisture content, and other variables, is carefully controlled.

3. The wood chips are cooked for the prescribed time under the proper temperature and pressure. Usual cooking time is from 2-4 hours at about 100 to 110 p.s.i. While the wood is cooking, turpentine and other volatile constituents distill and these are condensed for sale as by-products.

4. At the end of the cook the pulp and liquor are "blown" into the blow tank. The pressurized steam in the digester is the blow propellant, and it blows the digester clean, ready for another cook. The steam from the blow is utilized to heat water for mill use.

FIGURE II

GROUNDWOOD MILL OPERATION



5. In the blow tank are the pulp and the black liquor containing the spent cooking chemicals, as well as lignin and other solids extracted from the wood. The pulp and black liquor are diluted with dilute black liquor and pumped through the de-knotters to the brown-stock washers, where the liquor, containing the soluble residue from the cook, is washed out of the pulp.

6. The washed pulp is then screened and sent to the bleach plant or paper mill. A portion of the black liquor from the washers is used as a diluent for the cooking liquor and blow-tank stock. The remainder is sent to the recovery unit of the pulp mill, where the cooking chemicals are reclaimed.

Recovery is an essential part of the sulfate process. If all the spent cooking chemicals were sewered, the cost of the process would be prohibitive, and stream pollution would be sufficiently severe to preclude operation on inland waters. The recovery of the chemical and heat from the sulfate spent liquor is summarized in the following steps:

1. The black liquor from the brown-stock washers, containing about 16% solids, is evaporated in multiple-effect evaporators to about 50% solids. During evaporation, soap is separated for sale as a by-product.

2. The liquor is further concentrated in a direct-contact evaporator. The solids content now will be about 65%.

3. The thick liquor is now burned in the recovery furnace. Lignin and other extracts from the wood maintain combustion, and the cooking chemicals form as a smelt at the bottom of the furnace. Sodium sulfate present in the liquor and that added as a makeup chemical is reduced to sodium sulfide. Heat from the furnace is utilized to produce superheated steam for the mill's turbogenerators as well as process steam.

4. Smelt from the recovery furnace is dissolved, and "green liquor" is formed. This "green liquor" contains mainly sodium sulfide, sodium sulfate, and sodium carbonate.

5. Green liquor is then causticized, sodium carbonate is converted to sodium hydroxide, and calcium precipitates out as calcium carbonate.

$$Ca(OH)_2 + Na_2CO_3 \longrightarrow CaCO_3 \downarrow + 2NaOH \quad \ldots (1)$$

6. The calcium carbonate precipitate formed as shown in equation (1) is burned in a large rotary kiln to reclaim the calcium:

$$CaCO_3 \rightarrow CaO + CO_2 \uparrow \quad \ldots (2)$$

7. Calcium oxide formed as shown in equation (2) is slaked with wash water or dilute liquor to furnish calcium hydroxide for causticizing green liquor, as in equation (1):

$$CaO + H_2O \rightarrow Ca(OH)_2 \quad \ldots (3)$$

Makeup lime is added either as raw lime or as calcium carbonate.

8. Sodium hydroxide formed as shown in equation (1) is sent to the digesters as cooking liquor, thus completing the recovery cycle. This sodium hydroxide solution ("white liquor") also contains the sodium sulfide formed in the recovery furnace.

(2) Soda Pulp.

The manufacture of soda pulp is very similar to that of sulfate pulp, both being alkaline processes. The woods used are of the deciduous or broadleaf variety. Poplar makes up the largest tonnage and is also the easiest to cook. Other woods employed include birch,maple, chestnut, gum, and basswood. Owing to the tendency of broadleaf woods to sink, it is usually necessary to ship them by rail or truck to the mill rather than to float them in. The preparation of the wood for cooking is similar to that described previously under Wood Processing.

The digesters are very similar to the digesters used in the sulfate process and are constructed of steel or wrought-iron plate, likewise unlined. The cooking time varies from 2 to 3 hr. at a pressure of 110 lb. per sq. in. and a temperature of 344°F. The digesters are usually blown to blow pits which have provisions for heat exchange to utilize the steam. The pulp is washed in an open tank with a false bottom constructed of heavy steel plate covered with a fine wire netting. The plate is perforated with 1/2 in. holes, closely spaced. The remaining operations are very similar to those used for processing sulfate pulp.

The black liquor from the soda pulp contains about 16 percent total solids and 4.5 percent total alkali. Most of the latter is sodium carbonate, the remainder being free sodium hydroxide. This liquor is concentrated by multiple-effect evaporation as in the sulfate process and fed to either stationary furnaces or rotary driers. No smelting furnace is used ordinarily, the product being a black ash containing 20 to 25 percent free carbon. This ash is charged to a series of leaching tanks equipped with false bottoms. The ash is leached counter-currently with water or weak alkali, the resulting solution being fed to the slaking tanks and the carbon waste discarded.

Recovered lime is added to the liquor in the slaking tank and the slurry fed to the causticizing tanks, where make-up sodium carbonate is added. The reaction taking place is essentially:

$$Na_2CO_3 + Ca(OH)_2 \longrightarrow 2\ NaOH + CaCO_3$$

The calcium carbonate sludge is filtered off and sent to the limekilns. The filtrate is the white liquor used in the digesters.

Since the fibres from broadleaf woods are shorter (1½ mm.) than those from coniferous woods used in the sulfate process (2 to 3 mm.) the product of the soda process is a pulp that makes a weaker paper. Therefore, it is generally used with mixtures of other pulps, serving to fill in the spaces between the longer fibres. The largest tonnage of the pulp enters into the manufacture of book magazine and tissue papers.

(3) Sulfite Pulp

On the basis of quantity produced, this process ranks second only to the sulfate process. Although spruce is the wood most commonly employed, appreciable quantities of hemlock and balsam are also used. The wood is barked, cleaned, and chipped with the resulting chips being about 1/2 in. in length. It is then conveyed to the storage bins above the digesters, preparatory to being cooked.

The chemistry of the sulfite digestion of cellulosic materials is very complicated, and the thermodynamic data are incomplete and not very reliable. The external energy required for the process includes steam for the preparation of the cooking liquor and cooking the pulp, and mechanical energy for chipping the wood and pumping.

The more common sulfite process consists of the digestion of the wood in an aqueous solution containing calcium bisulfite and an excess of sulfur dioxide. The sulfite process involves two principal types of reactions, which are probably concurrent: (1) the reaction of the lignin with the bisulfite, and (2) the hydrolytic splitting of the cellulose-lignin complex. The hemicelluloses are also hydrolyzed to simpler compounds, and the extraneous wood components acted on. Since the disposal of waste liquor (more than half of the raw material entering the process appears here as dissolved organic solids) is a serious pollution problem, concerted attention has been turned to its disposal or utilization. Substituting magnesium oxide for lime is being evaluated commercially because chemical and heat recovery are possible accompanied by a solution of the disposal problem of the waste liquor. Sodium and ammonia have also been substituted for calcium as a pulping base and are used in a limited number of commercial plants. So far, costly and complicated chemical recovery limits their widespread use. The calcium-based sulfite-pulping process will now be described.

Two methods of preparing the cooking liquor (tower and milk of lime) and two methods of cooking (direct and indirect) are widely used. The essential reactions involved in the preparation of the cooking liquor are quite simple.

$$S + O_2 \rightarrow SO_2$$

$$2SO_2 + H_2O + CaCO_3 \rightarrow Ca(HSO_3)_2 + CO_2$$

The entire process may be divided into the following unit operations and unit processes.

1. Sulfur is melted in a tank heated by the rotary burner and then fed to this burner for oxidation.

2. Any sulfur that is vaporized in the burner enters a combustion chamber, where it is oxidized to sulfur dioxide. The amount of air in this operation is closely controlled to prevent the formation of sulfur trioxide.

3. The sulfur dioxide obtained is cooled quickly in a horizontal, vertical, or pond cooler consisting essentially of a system of pipes surrounded by water. In all but the pond system, the water is sprayed on the outside of the pipes.

4. The next step in the process is the absorption of the gas in water, in the presence of calcium and magnesium compounds. This is accomplished in a series of two or more absorption towers packed with limestone. A fine spray of water passes down through the tower system countercurrent to the sulfur dioxide gas, which is blown up through the tower.

5. The liquor leaving the towers contains a certain amount of free sulfur dioxide, which is enhanced from time to time as the free sulfur dioxide vented from the digesters is bubbled through it in the "reclaiming tower" that follows. The final liquor as charged to the digesters is a solution of calcium and magnesium bisulfites, analyzing about 4.5 percent "total" sulfur dioxide and about 3.5 percent "free" sulfur dioxide. The digester is filled with chips and the acid cooking liquor is pumped in at the bottom. The digesters are cylindrical steel vessels with a capacity of from 1 to 23 tons of fibre and 3,000 to 51,000 gal. of "acid". A special lining of cement, crushed quartz, and acid-resisting brick is used to avoid the corrosive action of the cooking liquor.

6. The digester is heated with direct steam. In recent years, the industry has turned to digesters with forced outside circulation which heat the cooking liquor in an outside stainless-steel tube heater and circulate it through the charge by means of pumps.

This permits a better temperature distribution through the charge and prevents dilution of the liquor with the direct steam formerly used for heating. Conditions of the cook depend on the nature of the wood, the composition of the acid, and the quantity of pulp charged. The pressure varies from 70 to 160 lb. depending upon the construction of the plant. The time and the temperature range from 10 to 11 hr. and 105 to 155°C. (220 to 311°F) respectively.

7. At the end of the cooking process, the digester is discharged by blowing to a blow pit (a large, round tank having a false bottom and equipped with means to wash the pulp with fresh water). The cooking liquor is not recycled.

8. The pulp is pumped from the pit to a series of screens where knots and large lumps of fibre are removed.

9. The accepted stock from the screens is sent to the rifflers (a series of long felt-lined troughs equipped with cross bars every 6 ft.). The foreign matter in the pulp gradually settles out.

10. The relatively pure pulp is concentrated in thickeners which are cylindrical frames covered with 80-mesh bronze wire. The water passes through and the pulp is retained on the screen.

11. The pulp is sent to the bleacher, and free chlorine is introduced. After the chlorine has been exhausted, milk of lime is added to neutralize the mass.

12. The stock is washed, thickened, and sent to the machine chest.

13. Pulp from the chest is formed into laps of about 35 percent dry fibre content, and the laps are dried with steam-heated rolls to a product which is 80 to 90 percent dry fibre.

The milk-of-lime system of preparing the cooking liquor consists of slaking burnt lime containing a high percentage of magnesia with warm water to produce a suspension. A high percentage of magnesia is desirable because the magnesium sulfites formed are more soluble than the corresponding calcium compounds. The calcium compounds tend to settle out and clog the pipes. This solution is treated with sulfur dioxide gas to produce the cooking liquor.

Sulfite pulp is a high-grade type of pulp and serves for the manufacture of some of the finest papers embracing the bond office line.

It is used either alone or with some rag pulp to make writing paper and high-grade book paper. A simplified flow diagram of the sulfite mill operation appears in Figure III in the Appendix.

A comparison of the three types of chemical pulping appears in the following table:

Table I. A comparison of three types of chemical wood pulp.

Type of process	Sulfate pulp	Sulfite pulp	Soda pulp
Cellulosic raw material.	Almost any kind of wood, soft or hard.	Coniferous; must be of good color and free of certain hydroxy phenolic compounds.	Limited to short-fibered hardwoods because of low yields and pulp strength, e.g. poplar, birch, maple.
Principal reaction in digester.	Hydrolysis of lignins to alcohols and acids; some mercaptans formed.	Reactions occurring are very complex and not yet fully understood.	Hydrolysis of lignins to alcohols and acids.
Composition of cooking liquor.	12.5% solution of NaOH, Na_2S and Na_2CO_3. Typical analysis of solids. 58.6% NaOH, 27.1% Na_2S, 14.3% Na_2CO_3. Dissolving action due to NaOH and Na_2S. Na_2CO_3 inactive and represents the equilibrium residue between lime and Na_2CO_3 in the formation of NaOH.	7% by weight SO_2 of which 4.5% is combined as sulfurous acid and 2.5% as $Ca(HSO_3)_2$. Cooking 1 ton of pulp requires 225 to 300 lb. of sulfur and 350 to 400 lb. of lime rock.	12.5% solution of NaOH and Na_2CO_3 in the ratio 85 to 15; dissolving action due solely to NaOH.

(continued)

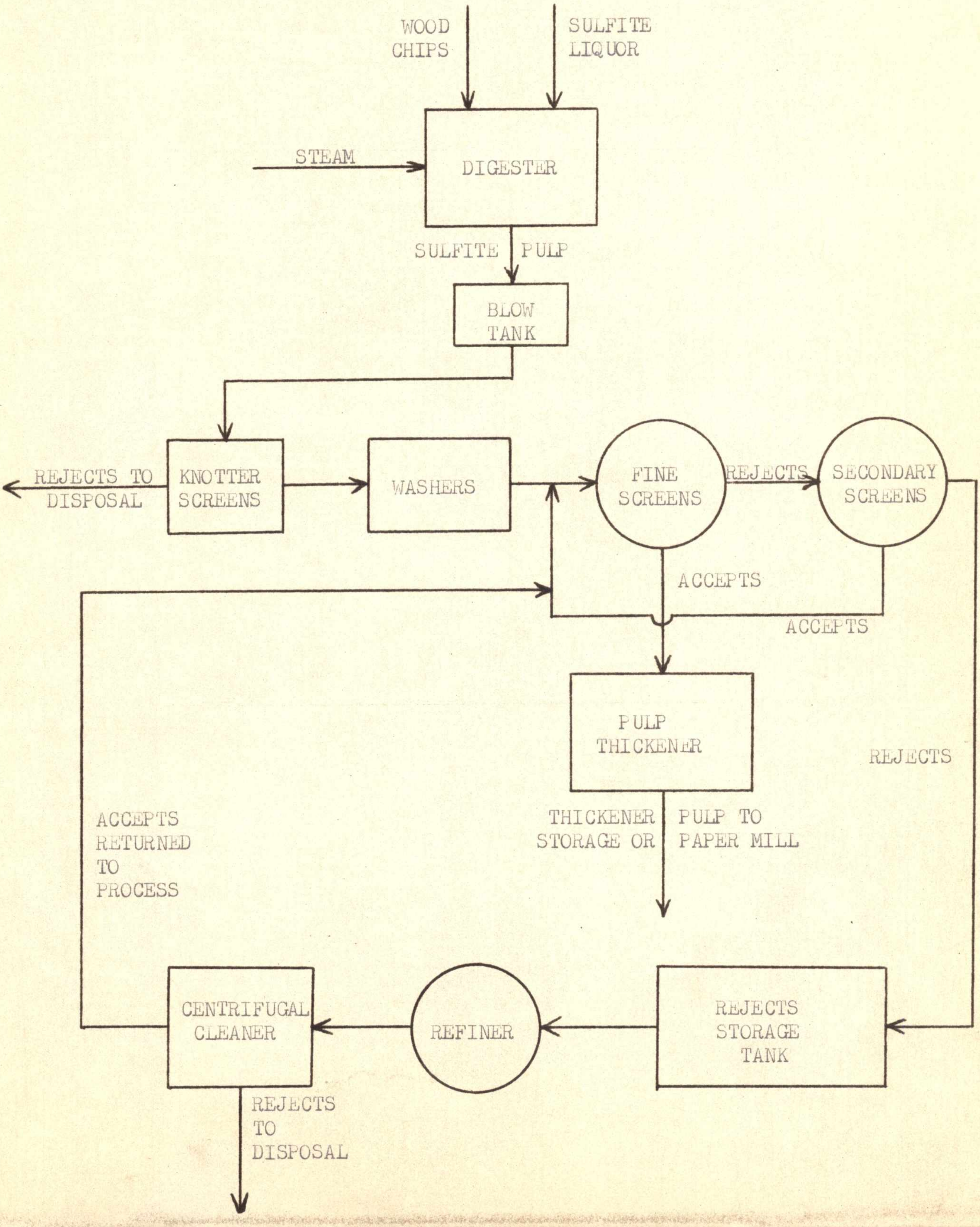
(Table I ... continued)

Type of process	Sulfate pulp	Sulfite pulp	Soda pulp
Cooking conditions.	Time: 2-5 hr. Temperature: 340-355°F. Pressure: 100-125 lb. per sq. in.	Time: 7-12 hr. Temperature: 265-300°F. Pressure: 70-90 lb. per sq. in.	Time: 6-8 hr. Temperature: 330-340°F. Pressure: 90-105 lb. per sq. in.
Chemical recovery.	Chemicals too expensive to discard; therefore, most of process is devoted to recovery of cooking chemicals with incidental recovery of heat through burning organic matter dissolved in the liquor from the wood; chemical losses from system are replenished with salt cake, Na_2SO_4.	SO_2 relief gas recovered; liquor discarded after wood digestion and pulp washing; little present salvage of chemicals but use of waste liquor being extensively studied.	Sodium hydroxide recovered and reused as in kraft process, but make-up chemical is Na_2CO_3 instead of Na_2SO_4.
Materials of construction.	Digesters, pipe lines, pumps, and tanks can be made of mild steel or iron because caustic liquor does not readily corrode them.	Acid liquor requires digester lining of acid-proof brick; fittings of chrome-nickle steels lead, and bronze.	Same as kraft materials.
Pulp characteristics.	Brown color; difficult to bleach; strong fibres; resistant to mechanical refining.	Dull white color; easily bleached; fibres weaker than kraft.	Brown color; easily bleached; fibres weaker than kraft or sulfite.

(continued)

FIGURE III

SULFITE MILL OPERATION



(Table I ... continued)

Type of process	Sulfate pulp	Sulfite pulp	Soda pulp
Typical paper products.	Strong brown bag and wrapping; multiwall bags, gumming paper, building paper; strong white papers from bleached kraft; paper-boards such as used for cartons, containers, milk bottles, and corrugated board.	White grades; book paper, bread wrap, fruit tissue, sanitary tissue.	Usually blended with other pulps; book and magazine grades, coated papers, sanitary tissue.

D. Bleaching

Wood pulp, regardless of the process by which it is made, must be bleached if it is to be used in any of the finer varieties of light colored papers. Conversely, bleaching is seldom required for the lower grades of paper. As an example, consider newsprint made from a combination of the sulfite and groundwood pulps. The sulfite pulp does not require bleaching and the groundwood pulp is bleached only on rare occasions.

Wood pulp, no matter how carefully made, and whether produced by the sulphite or the alkaline processes, always has associated with the cellulose a portion of the lignin or incrusting matter ordinarily present in the raw fibre and this lignin carries with it certain colored bodies of highly complex chemical composition. These colored impurities cannot be removed by any amount of washing or mechanical treatment. They are united in a chemical manner with the fibre or cellulose and a chemical process is necessary for their removal.

In addition to the colored materials that are ordinarily present in the fibre, other dark colored substances are produced during the process of digesting the pulp, by the chemical action of the acid or alkaline liquids on the various complex substances contained in natural wood.

Soda pulp should be very thoroughly washed before bleaching or there will be great waste of chlorine due to the affinity of any residual black liquor for chlorine. Thoroughly cooked and washed soda pulp is best bleached at about 12 percent consistency at a temperature of about 90°F.

The object of all successful bleaching practice in the paper industry is to thoroughly bleach the pulp so as to turn out a product of maximum whiteness and purity, which will remain white indefinitely, and, at the same time, not to impair the strength and natural properties of the fibre, not to cause too much shrinkage in weight and volume, and not to have an excessive consumption of the bleaching agent.

Naturally, as in any other process, it is also desirable to reduce the labor employed in the process to a minimum and consequently, whereas bleaching was formerly carried out in simple tanks provided with more or less crude agitators, at the present time numerous highly efficient special forms of bleaching equipment are on the market, all of which are designed with the idea of making the process as largely automatic as possible.

Bleaching is essentially an oxidising reaction. This is shown by the fact that many materials will become bleached when simply left exposed to the wind and weather. All of the various chemicals used for bleaching purposes are used with the idea of oxidizing the colored materials and, of all these bleaching agents, the most common are certain of the compounds of chlorine. Chlorine, when brought in contact with water, releases the oxygen of the water and it is this freshly released oxygen that exerts the decolorizing action on the fibre.

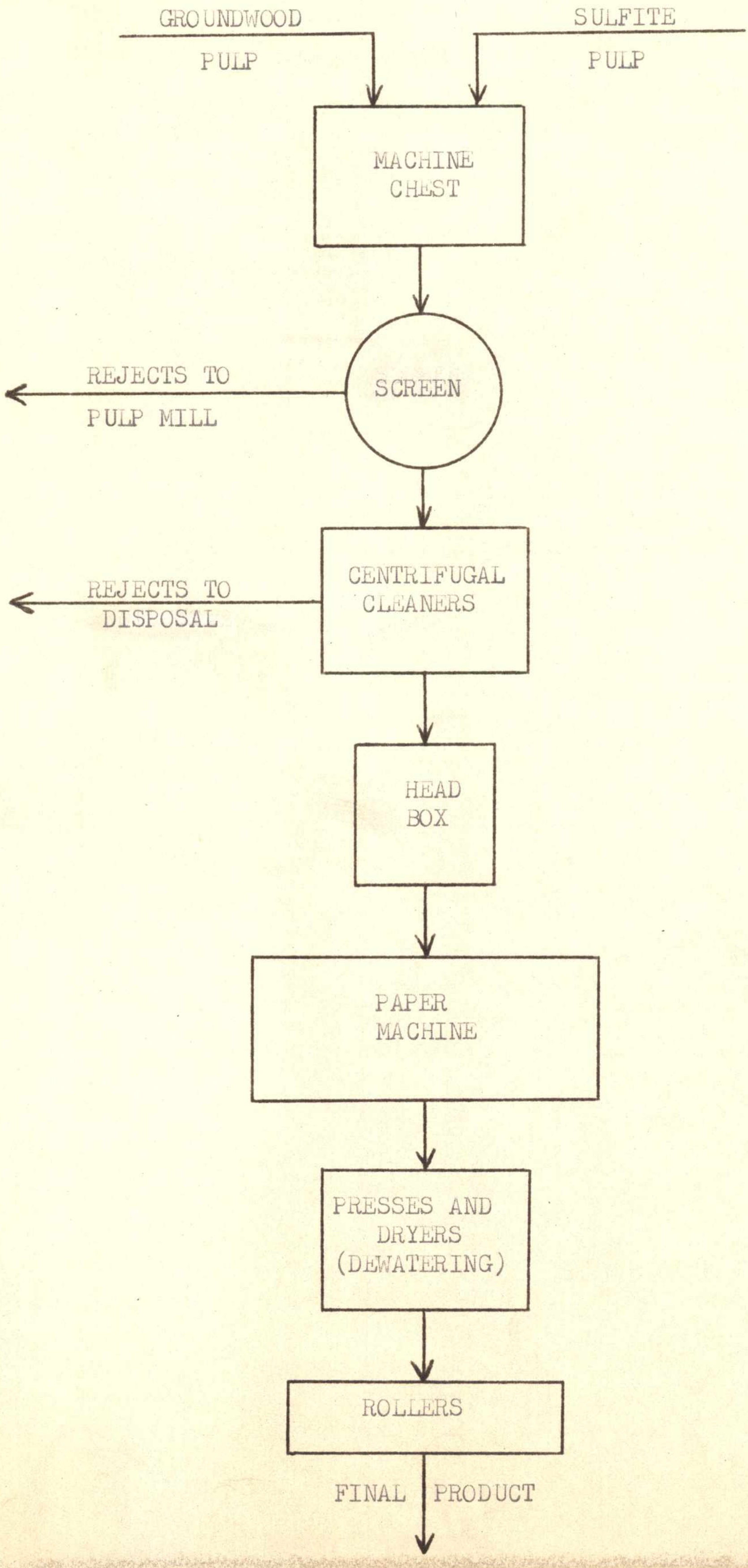
E. Paper Manufacture

The various pulps, even though frequently manufactured in coarse sheets, still lack those properties which are so desirable in a finished paper, such as proper surface, opacity, strength, and feel. Pulp stock is prepared for formation into paper by two general processes: beating and refining. There is no sharp distinction between these two operations. Mills use either one or the other alone, or both together.

The most generally used type of beater consists of a wooden or metal tank having rounded ends and a partition part way down the middle, thus giving a channel around which the pulp circulates continuously. On one side is a roll, equipped with knives or bars, and directly below this a bedplate consisting of stationary bars. In operation, the circulating pulp is forced between the bars on the revolving roll and the stationary bars of the bedplate. The roll itself may be raised or lowered to achieve the results desired. Beating the fibres makes the paper stronger, more uniform, more dense, more opaque, and less porous. It is in the beater that fillers, coloring agents, and sizing are added. Since the beaters are batch machines some mills making lower grades of papers have done away with them entirely and use only refiners. The standard practice in making the finer grades of paper, however, is to follow the beaters with the refiners, which are continuous machines.

FIGURE IV

PAPERMAKING OPERATION



A standard refiner consists essentially of a conical shell, on the inside of which are set stationary bars. Revolving inside the shell is a core, also set with bars. It is the action between these two sets of bars that produces the desired effect on the pulp. The latter enters the small end of the cone and, after being acted upon by the bars, passes out at the other end.

Filler, sizing, and coloring may be added either in the beater, which is usual practice, in the refiner or in both. The order in which these materials are added to the beater may vary in different mills, but generally, is as follows: (1) The various pulps are blended to give the desired density and uniformity. (2) The filler is added with or just after the fibre. (3) After sufficient beating, the size is put in and mixed thoroughly. (4) The color is added and distributed well throughout the mass. (5) The alum is introduced to produce coagulation and the desired coating of fibres.

All papers except absorbent types, i.e. tissue or blotting paper must have a filler added to them, the purpose of which is to occupy the spaces between the fibres, thus giving a smoother surface, a more brilliant whiteness, increasing printability, and an improved opacity. The fillers are always inorganic substances and may be either naturally occurring materials, such as talc or certain clays, or manufactured products such as suitably precipitated calcium carbonate, blanc fixe, or titanium dioxide. All are finely ground.

Sizing is added to paper to impart resistance to penetration by liquids. Again, the only papers not so treated are blotting and other absorbent papers, where penetration is desired. The sizing may either be added in the beating operation or applied to the surface after the sheet is formed. The process of engine or stock sizing, i.e., adding size in the beater, involves the addition of the sizing agent, consisting of either a soap made from the saponification of rosin with alkali or a wax emulsion, followed by precipitation of the size itself with papermaker's alum, $Al_2(SO_4)_3 \cdot 18H_2O$. This treatment gives a gelatinuous film on the fibre, which loses water of hydration and produces a hardened surface.

Tub sizing, on the other hand, is carried out on the dried paper, or sufaces which may or may not have been previously and partly sized in the beating operation. The material used for this treatment must have adhesive properties, the principal substances being animal glue, modified starches, and wash sizes. The operation is carried out either on the paper-making machine itself or in a separate sizing press employing air drying. The paper runs through a bath of the size material, then through rolls that remove the excess material, and finally over drying rolls. This type of sizing operation is used further to enhance the water resistance of the paper and especially to make it take ink evenly without blurring, even after erasures.

Another material that is added to the paper is coloring. Approximately 98 percent of all paper produced has a certain amount of coloring material added to it. Coloring, like sizing, may be added either in the beater or after the paper has been made, although about 95 percent is added in the former manner. However, surface coloring, the latter method, uses less dye and requires the production of only one type of paper, which may be colored any shade later as needed.

All types of dyes (acid, basic, direct, sulfur) and all types of pigments (both natural and synthetic) are used as coloring agents. The acid dyes have no affinity for the cellulose fibres and must, therefore, be fixed to them by means of mordants. If the paper is colored in the beater, the alum that is added to precipitate the size will also act as a mordant for the dye.

Surface dyeing may be carried out either in the papermaking machine or in a separate piece of equipment. In either case, the process consists in passing the paper through the dye bath, removing the excess dye by means of press rolls, and drying.

The machines used for the actual formation of the paper sheet are of two general types: the Fourdrinier machine and the cylinder machine. The basic principles of operation (as shown in Figure IV) are essentially the same for both machines. The sheet is formed on a travelling wire or a cylinder, dewatered under rollers, dried by heated rolls, and finished by calendar rolls. A more complete description of the operation of the two paper machines follows.

1. Fourdrinier Machine

The stock from the foregoing operations, containing approximately 1/2 percent fibre, is first sent through screens to the head box, from which it flows through the sluice onto a moving, endless, bronze-wire screen. The pulp fibres remain on the screen while a great protion of the water drains through. As the screen moves along, it has a sidewise shaking motion which serves to orient some of the fibres and give better felting action and more strength to the sheet. While still on the screen, the paper passes over suction boxes to remove water and under a dandy roll which smooths the top of the sheet . Rubber deckle straps travel along the sides of the screen at the same speed and thus serve to form the edges of the paper.

From the wire, the paper is transferred to the first felt blanket which carries it through a series of press rolls, where more water is removed and the paper given a watermark if so desired. Leaving the first felt, the paper passes through steel smoothing rolls and is picked up by the second felt which carries it through a series of drying rolls heated internally by steam. The paper enters the rolls with a moisture content of 60 to 70 percent water and leaves them 90 to 94 percent dry. Sizing may be sprayed on the sheet at this point, in which case it must pass through another series of drying rolls before entering the calender stack which is a series of smooth , heavy, steel rolls which impart the final surface to the paper. The resulting product, finished paper, is wound on the reel. The enormous quantity of water used makes it necessary to recirculate as much of it as possible for economical operation.

The operation of a Fourdrinier is a very complicated procedure. One of the major problems is making suitable allowance in the speed of the various rolls for the shrinkage of the paper as it dries. The operating speeds of the machines vary from 200 ft. per min. for the finer grades of paper, to 1,700 ft. per min. for newsprint.

2. Cylinder Machine

For the manufacture of heavy paper, cardboard, or nonuniform paper, the cylinder machine is employed. It enables several similar or dissimilar layers to be united together into one heavy sheet. The cylinder machine has from four to seven parallel vats into each of which similar or dissimilar dilute paper stocks are charged. A wire-covered rotating cylinder dips into each vat. The paper stock is deposited on the turning screen as the water inside the cylinder is removed. As the cylinder revolves farther, the paper stock reaches the top where the wet layer comes into contact with and adheres to a moving felt. The travelling felt carrying the wet sheet underneath passes on under a couch roll to press out some of the water. This felt and paper come into contact with the top of the next cylinder and pick up another layer of wet paper. Thus, a composite wet sheet or board is built up and passed through press rolls and on to the drying and smoothing rolls. Such a composite may have the outside layers of good stock while the inside ones may be of ground-wood pulp.

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THE POLLUTION PROPERTIES OF PULP AND PAPER MILL WASTES

The total effluent from a pulp mill consists of liquid wastes from the various mill processes, washings from plant operations and general plant sewage. It is largely fresh water contaminated in varying degrees by dissolved and particulate wood products as well as by chemicals lost from the digestion and bleach processes. Table II indicates water usage in the groundwood, kraft, soda and sulfite mills.

Table II. Average waste discharge per ton of paper product.

Product	Waste, American gal.
Pulp mills	
Groundwood	5,000
Soda	85,000
Sulfate (kraft)	64,000
Sulfite	60,000

Pulp mill wastes may be classified into two basic categories, as arising from (a) chemical digestion and (b) mechanical pulping. A semi-chemical pulp is also produced in small quantities by light chemical digestion followed by mechanical disintegration. The spent liquor from chemical digestion contains the salts used in the "cooking" process, as well as the organic materials binding the cellulose fibres in the wood that have been dissolved during digestion. Mechanical pulping consists of the grinding of wood blocks on stone wheels in the presence of water. Effluent from this process contains only a small amount of dissolved organic substances leached from the wood and a considerable amount of small fibres.

Chemical digestion is further sub-divided into two basic types: (1) acidic (sulfite) process, where a solution of sulphurous acid combined with calcium, magnesium or other base is used for cooking the wood; and (2) alkaline (sulphate) process where a solution consisting mainly of sodium hydroxide and sodium sulphide is used.

The chemical characteristics of wastes are quite different from one chemical process to another. There are a number of physical properties, however, which are generally common to most wastes from all chemical pulping.

Some of the constituents dissolved from wood give effluents from chemical processing of pulp certain surface-active properties. The tendency to foam is a direct result of low surface tension of the effluent. Although foam itself is not especially harmful to organisms, it impairs the aesthetic qualities of surface waters. Its affinity for particulate materials in the effluent and other foreign matter on the water surface contributes to small accumulations of undesirable materials along the shores.

Aside from foaming characteristics, the rate with which water can be re-oxygenated is dependent on the amount of surface-active material present in the water. Large quantities of detergents are known to reduce the rate and amount of oxygen uptake by sewage treatment plant effluents. It is probable that the same effect prevails in the uptake of oxygen by waters containing large amounts of effluent from chemical pulping.

The density of effluent is variable from mill to mill and may vary over a period of time in the same mill, depending on the amounts of dissolved salts and organic materials which are wasted. In general, it is only slightly heavier than natural fresh water but considerably lighter than sea water. The surface active properties of pulp mill effluents ensure than they will disperse rapidly if they are injected into water having approximately their density. Consequently, it can be expected that the effluent will mix freely with fresh water but will tend to spread on the surface of sea water. Under the normal condition of stratification, with light water at the surface and denser water below in the coastal marine environment, the effluent tends to mix only in the upper brackish layer if it is discharged at the sea surface.

(a) Sulphite Pulp Mill Wastes

There is very little recovery practised in the sulphite process, except in some of the modern mills where a recoverable base (magnesium, ammonia, or sodium) is used. Sulfite waste liquor (SWL) is an amber-colored fluid rich in organic substances. It is noted mainly for its oxygen-consuming qualities. On a population equivalent basis, the oxygen consumption of effluent from a 500-ton-per-day sulphite mill may be equivalent to that of sewage from two million persons. The high concentration of wood sugars in the SWL results in rapid decomposition by bacteria and, consequently, a high B.O.D. (biochemical oxygen demand). There are numerous other organic constituents, of which lignin is the most significant, but they are generally more resistant to bacterial attack. These compounds are comparatively non-toxic, except for perhaps methyl alcohol, formic acid and furfural, which are present only in small concentrations.

Depending on the grade of sulphite pulp produced and the digester liquor base, the amount of wood substance discharged as waste can vary from

50 to 63 per cent of the raw material. When the spent chemicals released in the waste are also taken into consideration, there is a total solids discharge per ton of pulp (dry weight) which varies from about 3000 lb. to 4000 lb.

Unused sulphur dioxide, present in wastes in the form of sulphurous acid, can be toxic to fish. It can be responsible also for the lowering of dissolved oxygen concentration in receiving waters by its powers of chemical reduction. Sulphurous acid may be the principal contributor to the immediate oxygen demand (I.O.D.) which amounts to approximately 10 per cent of the total 5-day B.O.D.

Tables III and IV illustrate the percentage composition of the major components of the sulfite waste liquor and the composition of a typical sulfite pulp plant waste respectively.

Table III. Relationship of major components of sulfite waste liquor.

Component	% Total solids, bone-dry basis
Lignin	51.6
Sugars	16.9
Sulfur	9.15
Calcium	4.5

Table IV. Composition of a typical sulfite pulp-plant waste.

Component	Digester liquor, ppm	Blow-pit liquor, ppm
Total solids	111,100	38,700
Volatile solids	101,000	34,000
Ash	10,100	4,700
Calcium	3,990	1,550
Total sulfate	31,200	8,620
BOD, 20-day	42,900	

(b) Kraft Pulp Mill Wastes

Recovery of the spent cooking solution ("black liquor") from the digestion operation is practised as an integral part of the kraft process, by which certain economics in heat and salt recovery are realized. Kraft mill effluent (KME) usually consists of washings from the various screening and bleaching processes that cannot be recirculated, dregs from the causticizing plant, condensates, floor drainage, other unusable residues and sanitary sewage. Because sodium sulphide is used in the cooking liquor, certain toxic sulphur-containing compounds emerge with the black liquor. Hydrogen sulphide and mercaptans are the most noteworthy components of this group, and they are generally responsible for the notoriety of kraft pulp mills in atmospheric pollution. In addition to the sulphur compounds, KME also contains tall oil, resin and fatty acid soaps derived from the black liquor and usually separated in the recovery plant. While the sulphides and mercaptans are quite unstable and seldom occur in dangerous concentrations beyond the sewer outfall, the resin and fatty acid soaps are relatively stable and may be the major contributors to the toxicity of kraft pulp mill wastes.

The B.O.D. of kraft mill effluent is comparatively low, being about one-tenth of that of the sulfite waste liquor. However, in many instances, the B.O.D. from a particular kraft mill can cause considerable harm to the freshwater or marine environments receiving the wastes. The tendency to ignore the effects of B.O.D. loading from a kraft mill or write off the B.O.D. as a minor problem in kraft mill pollution control should be avoided. The deep brown colour often associated with kraft mill effluent is characteristic of the form of lignin released by the kraft process. It does not represent a particularly toxic condition nor one of high B.O.D. but only the presence of a coloured material which happens to be a fairly sensitive tracer for the waste. A typical analysis of a kraft mill waste appears in the following table:

Table V. Characteristics of kraft mill wastes.

Characteristics	Maximum	Minimum	Average
pH	9.5	7.6	8.2
Total alkalinity, ppm	300	100	175
Phenol alkalinity, ppm	50	0	10
Total solids, ppm	2000	800	1200
Volatile solids, %	75	60	65
Total suspended solids, ppm	300	75	150
Volatile solids, %	90	80	85
BOD, 5-day, ppm	350	100	175
Color, ppm	500	100	250

(c) Bleach Plant Wastes

Bleach plant effluent is one of the less harmful components of pulp mill sewage. There is, however, a certain amount of B.O.D. associated with bleach effluent which may be as high as that of KME. The first bleaching stage in a kraft pulp mill consists of chlorination followed by a caustic extraction, wherein the dark-coloured constituents attached to the fibres form chlorinated lignin and are removed by dissolving with sodium hydroxide solution. Effluent from this stage is not recirculated but wasted to the sewer. Most of the dark brown pollution characteristics of a full-bleach kraft pulp mill originate from this operation. Presence in the wastes of residual calcium hypochlorite, chlorine and chlorine dioxide used in the other bleaching stages can actually benefit the oxidation processes acting on the organic materials present in the mill wastes. It is usually recommended that bleach plant wastes be mixed with the other mill wastes before release into the sea. An added advantage in admixture of spent zinc hydrosulphite bleach solution, where bleaching of groundwood for newsprint is practised using this chemical, is that foaming of the total mill effluent can be appreciably reduced.

(d) Groundwood, Woodroom and Paper-machine Wastes

Wastes from mechanical pulping and other non-chemical wood processing operations are harmful to the marine environment, mainly by virtue of the high concentrations of suspended particulate materials. Groundwood, produced by mechanical grinding is used mainly in the production of newsprint. The addition of kraft or sulphite pulp provides longer fibres to give the paper strength. Some of the groundwood pulp is lost to the sewer in various stages of processing and in the formation of paper. There is a nominal B.O.D. associated with groundwood wastes arising from decomposition of raw organic constituents leached from the wood. This is considered only incidental when the groundwood mill is part of a much larger chemical pulp plant.

Woodroom operations, such as hydraulic or mechanical barking and sawing, yield effluents that are sometimes highly discoloured from the bark extracts and contain a great deal of particulate material in the form of bark fragments, knots, wood chips and slivers. Effluents from woodrooms of most mills are at least coarse-screened before being released. However, there are still large amounts of particulate materials settling out in fresh waters as well as in the sea adjacent to pulp mills. While dissolved chemical constituents are mainly responsible for the acute effects of toxic and low-oxygen conditions, the accumulation of particulate materials often leads to harmful long-term effects. A typical analysis of wood preparation wastes appears in the following table:

Table VI. Typical analysis of wood preparation wastes.

Characteristic	ppm
Total solids	1160
Suspended solids	600
Ash suspended solids	60
Dissolved solids	560
Ash dissolved solids	240
BOD, 5-day	250

Effluent from paper-machine operations has a characteristic milky appearance and is commonly referred to as "white water" in the parlance of the pulp and paper trade. White water consists of a suspension of fine fibres, essentially in colloidal form. In the production of specialty printing papers, where clay or other sizing materials are used to give the paper gloss, the amount of colloidal material is often increased. Discharged into fresh water, such effluents disperse by dilution without appreciable settling of particulate, colloidal materials. The flocculating effect of sea water tends to precipitate the solid constituents when the wastes are released into the marine environment. Table VII illustrates a typical analysis of white water wastes.

Table VII. Analysis of white-water waste.

Characteristic	Value or concentration
pH	7.0
Alkalinity, ppm $CaCO_3$	118
Suspended solids, ppm	840
Fixed solids, %	11.9
Volatile solids, %	88.1
Total solids, ppm	2180
Ash, %	19.3
Volatile total solids, %	80.7
Dissolved solids, % of total	61.5
BOD, ppm	100-400

In the following table, a comparison is made between wastes from kraft, sulfite and groundwood mills. The data was obtained from a survey conducted in Wisconsin in 1946.

Table VIII. Results of 1946 survey of wastes at Wisconsin pulp and paper mills.

Type of paper or pulp mill	Waste, gal/ton product	Solids, lb/ton of product			Fibre loss, % of production	BOD, 5-day population equivalent persons/ton product.
		Fixed suspended	Volatile suspended	Total soluble		
Kraft pulp	64,838	33.6	61.2	329.8	3.1	451
Sulfite pulp	50,470	3.7	37.6	2413.8	2.0	2857
Groundwood pulp	2,302	0.15	11.2	7.0	0.6	20

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PULP AND PAPER MILL WASTE DISPOSAL IN THE MARINE ENVIRONMENT

A. Forces Affecting Dilution and Dispersion of Wastes in the Sea

The objective in effective waste disposal into any environment is dilution to low concentrations and dispersion away from the source of the waste. In the sea, there are a number of static factors and dynamic forces which determine the extent to which these desirable pollution preventing processes can occur.

The geography of a given coastal marine area provides the confining horizontal boundaries within which the dynamic processes can act. The configuration of the bottom topography imposes a vertical limitation on these processes. The bottom contours can influence the degree of turbulent mixing that occurs when a current flows past.

Turbulent mixing provides the dilution mechanism, whereas advection (currents) provides for transport and dispersion of the wastes from the source of pollution. Three causes in the sea contribute toward mixing and advection — tides, freshwater runoff and winds. The tide is a feature of the sea which makes it different from the freshwater environment. The rhythmic rise and fall of sea water provides mixing and advection, the extent of which depends on the geography and topography of the particular area. In channels connecting large bodies of water, the tides can be very effective in mixing the wastes with the sea water, vertically and horizontally, and then transporting them out of the area. The magnitude of tidal mixing and transport is dependent on the range of the tide, other factors being equal.

Freshwater runoff renders an effect in the sea similar to that present in a river. The seaward flow of fresh water over the sea water provides a vehicle for transporting the wastes out of the area of pollution toward the open sea. By entraining sea water from below, however, this freshwater layer may, in fact, create a much greater volume of water for dilution and transport than that available from the original runoff. To replace the sea water removed by entrainment in the fresh water, there is a net flow of sea water inward at intermediate depths.

Winds in the sea, as in lakes or streams, provide mixing mainly in the upper layer, although the depth of this layer in the sea can be quite large. They can also effect transport of wastes in the surface layer through wind-driven currents. The greatest advantage of winds as a mixing and dispersing force can be gained in open coastal waters where a strong wind blows offshore.

B. <u>The Effect of Mill Wastes on the Marine Environment</u>

There are two types of effects of pulp mill wastes in terms of time when they become apparent in the marine environment: A. Immediate and B. Longterm. The immediate effects are those which are manifested in physical and chemical changes of the water immediately after receiving wastes without the later consequences to the bottom, water and biota. A full measure of the immediate effects can be obtained as soon as the inflow of mill wastes and the water system have reached an equilibrium. At that time, there is an equal amount of effluent being flushed out of the receiving waters to that entering. This balance shifts seasonally as the factors, such as runoff and winds, determining the flushing characteristics of the marine system change.

The long-term effects are those which occur gradually as a result of changes in the ecological conditions incurred by accumulation of certain undesirable materials. This is especially true of the effect of deposition of particulate materials from mill wastes on the bottom. Fibres and other solid mill wastes blanket the bottoms of marine waters and render them unsuitable for development and growth of marine benthic organisms. The populations of bottom-dwelling animals gradually shift from the sensitive species to more tolerant forms, and as conditions deteriorate further, even these forms may not be able to survive.

A. Immediate Effects

1. Chemical changes - inasmuch as most of the waste from pulp mills is chemical in nature, there are important effects which produce chemical alterations in the receiving waters.

(a) Dissolved oxygen concentration - The principal effect of pulp mill waste is the reduction of dissolved oxygen concentration in receiving waters. Two types of oxygen demands are imposed on the water by SWL - (1) "immediate oxygen demand", which is caused by the chemical reactions between oxygen and reduced sulfur compounds, mainly sulfur dioxide; (2) biochemical oxygen demand (BOD) due to the aerobic decomposition of organic constituents in the receiving water. In ordinary 5-day BOD determinations, the IOD amounts to about 11% of the total oxygen demand.

(b) Hydrogen-ion concentration - The introduction of highly alkaline Kraft digester wastes or acidic bleach plant wastes can produce changes in the pH of receiving waters. An indirect effect of pulp mill wastes on the pH of marine waters results from the shift of the bicarbonate - carbonate balance by the liberation of carbon dioxide from the decomposition of the mill wastes. However, sea water has a natural defense against large pH changes because of its high buffering capacity arising out of the presence of weak acid salts, bicarbonates and borates for example.

(c) Increase in other chemical constituents - Large amounts of dissolved organic and inorganic substances, such as lignin, sulfonates, calcium salts, and sulfur compounds from SWL; and caustic sodium salts, lignin, mercaptans and resin acids from the kraft mill effluent, are added to sea water in pulp mill wastes. This increases the concentration of these constituents in sea water with possible toxic effects on marine organisms.

2. Physical changes - certain physical properties of the sea water receiving pulp mill wastes are changed as a result of the physical nature of the wastes.

(a) Suspended materials - The suspended solids load of the wastes may be carried in the receiving waters for some distance but it generally settles out into sludge banks near the outfall. These settled solids contribute mainly to the long-term decay of the system.

(b) Color - The brown effluent contributes to the discoloration of the receiving waters. Secchi disc reading of 25 ft. in the clear water of an inlet is reduced to less that 5 ft. near an outfall from a sulfite pulp mill. This has a considerable ecological significance in that light penetration is reduced to 1/4 or 1/5 of normal depth, and phytoplankton production suffers accordingly.

(c) Temperature - A temperature rise in receiving waters can result, depending on the volume and temperature of effluent and that of the receiving waters.

Other physical properties undergo changes but are probably less important. For example, surface tension of sea water is lowered by the SWL and much foaming can occur under the action of wind stirring.

B. Long-term effects.

The build-up of materials, which settle out from pulp mill wastes, on the bottom of a marine system contributes to a change in bottom ecology. In the inter-tidal zone, the exposed rocks and gravel are often plated over with pitch-like substances from mill wastes making this usually-productive region unsuitable for the settling of invertebrate larvae. Through this adverse effect on the sessile fauna, the food of many fish is eliminated or heavily reduced. Moreover, the reduction of dissolved oxygen by decomposition of settled organic substances in the bottom material and in the water adjacent to it makes this zone entirely unsuitable for bottom fish.

While a complete change of water in a marine system following cessation of waste input might rapidly restore the original ecological conditions in the water itself, it would probably take a much longer period for the ecological balance between the bottom and the water to be restored. Long-term effects are difficult to assess over short periods. The error is often made in making one or two surveys after a particular polluting source is instituted and assuming that, if conditions are alright then, they will not change thereafter. Monitoring of physical, chemical, and biological conditions should be carried out annually. Changes are very subtle and creep up insidiously.

C. A Comparison of the Effects of Disposal of Pulp Mill Wastes in Fresh Water and in Sea Water

The basic effects of pulp mill pollution on the aquatic environment are the same in both fresh water and in the sea, namely:

(1) dissolved oxygen in the water is reduced to low concentrations by the decomposition of organic substances in the waste;

(2) the toxic constituents of pulp mill waste, particularly those in kraft mill effluent, are known to be harmful to fish;

(3) the particulate materials present in pulp mill effluents deposit on the bottom and modify the environment adversely for both bottom invertebrates and for any types of bottom fish present.

The basic differences of the effect of pulp mill pollution on the two environments stem from the salt content of sea water. Water of higher salinity has a higher density. Water of high salt concentration settles to the bottom while fresh water floats at the surface. This contributes to horizontal lamination where there are layers of water increasing in salt concentration with depth. Density stratification reduces the possibility of seasonal turnover of the water. Thus, exchange of bottom water in stratified marine areas is much slower than that in fresh waters.

The presence of weak acid salts in sea water, such as carbonates, borates and silicates, gives a higher buffering capacity in the marine environment than is available in fresh water. Strongly alkaline or acidic wastes are rapidly brought to the slightly alkaline conditions around a pH of 8, prevailing in sea water, as mixing and dilution in the sea take place.

Sea water acts as a strong electrolyte owing to the presence of highly-ionized salts, mainly sodium chloride. Consequently, it is a good conductor for an electric current, and this property is used in applications of various instruments, including devices for measuring salinity. The electrically-charged ions in saline solutions can also serve a function in the reaction of sea water with natural and artifically-introduced suspended materials. Silt-laden fresh waters are colloidal suspensions of very fine silica and clay particles. When these negatively-charged micelles of clay come into contact with positively-charged ions in sea water, there is neutralization of charge and the particles coalesce. Thus, flocculation of the silt brings about the deposition of heavier-than-water silt aggregates. In a similar way, although little is known quantitatively about it, the fibres present in pulp mill effluent are precipitated out in the sea by the flocculating effect of sea water.

While salts in water contribute to its "hardness" and prevent foaming of soaps and detergents, they appear to have little effect as an anti-foam agent with pulp mill effluent. Sea water, in fact, appears to enhance the frothing action of some of the black-liquor constituents of kraft mill effluent. The presence of sulphite wastes in the sea can be identified many miles from its source as a result of foam stirred up by wind mixing.

As a nutrient-rich source, sea water provides an ideal medium in which pulp mill wastes can decompose under the action of bacteria. Although terrestrial bacteria are rapidly destroyed by the properties which are unfavourable for their growth in the sea, marine bacteria are quite numerous and act in a way similar to land micro-organisms toward destruction of organic matter. In contrast to fresh water, however, sea water does not actively support the growth of some of the unsightly slime fungi.

The usually fertile conditions in coastal sea water provide a favourable environment for plant and animal life. Generally, the numbers of species and individuals of a particular species are much greater in the sea than in fresh water. However, there is the same delicate balance of organisms within the biological community and within the environment both in the sea and in fresh water.

While the oceans contain infinitely more water than lakes and streams, the amount of water available for dilution and dispersion in the sea may be severely restricted by certain characteristics of the marine environment. The matter of stratification has already been mentioned with respect to the nearshore marine environment, where there is considerable influence from freshwater runoff. Water movements in the sea are not always such that dispersion is invariably provided. There are exposed coastal areas where wastes released into the zone tend to be constrained in a narrow band along the coast because of onshore winds and alongshore currents. In contrast, there is a continuous flow of water in a river toward its estuary so that a steady replacement of fresh water occurs in the area of input of pollutant. Reaeration contributes to the well-known phenomenon of self-purification in freshwater streams. Similar processes occur in marine inlets where runoff contributes to a strong seaward flow at the surface, but reaeration is probably not as significant as in turbulent rivers.

A comparison between the characteristics of the freshwater and marine environments with respect to disposal of pulp mill wastes appears in Table IX.

Table IX. Comparison of the characteristics of the freshwater and marine environments with respect to disposal of pulp mill wastes.

Property or process	Fresh water	Coastal Sea water
Salt content	Low	High 2.0 to 3.5%
Horizontal stratification	Small	Large
Vertical stability	Low	High
Seasonal overturn	Occurs usually in autumn, when surface water reaches temperature of 4° C and its maximum density.	Seldom occurs if there is fresh water at the surface, because of dominant effect of salinity on density.
Dissolved oxygen replenishment	Replacement of bottom water allows a regular replenishment of dissolved oxygen.	Usually remains stratified with bottom water essentially stagnant and slow replenishment of dissolved oxygen therein.
Buffering capacity	Low, unless weak-acid salts present.	High, due to carbonates, borates and other weak-acid salts.
Flocculating action	Poor, unless flocculating agents present.	High, due to presence of strong electrolytes.
Bacteriacidal and fungicidal action	Not generally present.	High. Various marine properties and processes lead to destruction of terrestrial bacteria and fresh-water fungi.
Dilution and dispersion	Currents, due to gravitational force, provide principal mixing and transporting mechanism in streams.	Tides, runoff and winds generate mixing and transporting processes.

(continued)

Table IX. (continued)

Property or process	Fresh water	Coastal Sea water
Self-purification	Turbulence, aeration and algal growth in a stream usually lead to self-purification of the water.	Processes in the sea are generally less effective than those in fresh water for effecting self-purification of the water.
Aquatic organisms	Depending on fertility of water, amount of aquatic life may be low or quite high.	Dense flora and fauna in marine waters, especially along the coast, in nutrient-rich sea waters.
Silt content and presence of other particulate materials.	Varies from stream to stream.	Comparatively low in silt, except at river estuaries. Probably higher concentration of organic detrital materials than in fresh water.
Foaming properties	Soft-water stream or lake has marked foaming properties; foam forms when surface-active agents such as detergents and sulphite pulp mill wastes, are introduced in the presence of turbulence.	Salinity generally suppresses foaming tendency of soaps and detergents. High concentrations of sulfite waste liquor and kraft mill effluent in sea water cause foaming as high or higher than in fresh water.

D. Waste Disposal by Submarine Outfall

The early concept in sea disposal of waste from a pulp mill was that the effluent should be maintained at the surface of the sea water where it can benefit by maximum effects of aeration and can be transported seaward in the surface brackish layer. This was particularly emphasized in inlet disposal where there is generally a strong inflow of fresh water available for dilution and seaward transport. Disposers have often been cautioned not to discharge their wastes into the deep water where there is an inward flow and serious accumulation of wastes can occur.

More recent trends have been toward waste disposal by submarine outfall. The proper design of a submarine outfall with a diffuser can provide a substantial amount of immediate dilution as the effluent discharges at the bottom and rises turbulently to the surface. Besides reduction of high local water pollution, this system of disposal has its aesthetic values because the outfall is essentially concealed. When effluent leaves the diffuser, it immediately rises to the surface with considerable turbulent mixing. Depending on the elevation of the pipeline head tanks or the pumping force provided, there may be a great deal of kinetic energy associated with the jets of effluent discharging from the diffuser. In addition, there is the energy from the buoyant force resulting from the light effluent injected into dense sea water. If the water present at the depth of the outfall has an adequate loading of dissolved oxygen, then a suitable dilution water is provided which might not be available otherwise.

One of the problems that must be guarded against in submarine disposal is that so much dense sea water may be entrained with the effluent as it rises to the surface that it will sink again below the surface to depths, where it may accumulate. Ideally, the maximum immediate dilution possible is desirable with the effluent-seawater mixture remaining on the surface after it arrives there. This mixture can then be carried away by the seaward flow of surface water with further dilution enroute.

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PULP AND PAPER MILL WASTE TREATMENT

Pulp and paper mill waste treatment is still in its early stages, although a great deal of research and many pilot-plant investigations have been carried out and reported on. Actual treatment equipment is installed only after exhaustive study of all other possibilities, since the cost of treatment is considered high in relation to the cost of the product produced. In many instances, recovery of valuable components of the waste has been the most practical and economical solution.

A. Recovery Processes

Recovery processes in the mill involve the use of "savealls", either in closed or partly closed systems. These savealls are installed not only as a waste-treatment measure, but also as a conservation measure to recover fibres and fillers. The main types of savealls are based on filtration, sedimentation, or flotation processes. Filtration devices are usually some variation of a revolving, cylindrical, perforated screen or filter which removes the suspended solids in the form of a mat, which is subsequently scraped off the drum and returned to the papermaking stock system. Conical or other sedimentation tanks are also often used to separate the suspended matter from the water-suspended solids mixture. All the principles of sedimentation apply to these treatment units.

In flotation recovery units, the suspended fibre and other solids are removed in the form of a mat floating on the surface of the tank. This is a very efficient method for some types of fibres which have a natural tendency to float, being buoyed up by minute bubbles of air dissolved in the fibrous waste. The air is usually forced into the waste water under a pressure of about 45 pounds per square inch, and released in an open flotator tank under atmospheric pressure, or under a slight vacuum. Recovery efficiencies are often better than 95 per cent suspended solids recovered. Recovery of the clarifier white water is achieved by recirculating this water back into the beaters, head boxes, and showers. One difficulty encountered with recirculation of clarified white water has been slime growths, both in the mixture and on equipment. This greatly reduces the paper machine rates and lowers the value of the paper produced. Chlorination, organic mercurials, and environmental controls (pH and temperature) are used to control these growths.

The sulfite pulp mills use various methods of recovery. Equipment has been developed in which the sulfite waste liquor can be burned to produce enough steam to run the evaporator. (This process does not produce a saleable by-product, but merely eliminates the waste problem). Evaporation of the sulfite waste liquor produces a saleable by-product, and a fuel which can be burned without an additional outside fuel supply. This evaporation produces a substance which can be used in making core binder, insecticides and fungicides, linoleum cement, road binder, roadbank stabilizer, ceramic hardener, boiler compounds, synthetic vanillin, and other useful by-products. However, the main problem associated with these by-products has been the fact that the market cannot absorb more than five to ten per cent of them, in this country. Since evaporation is costly, due to the low initial concentration of solids in the sulfite waste liquor, and the boiler-scaling difficulties encountered, operation of such a process is limited to mills close to the users of waste liquors.

In addition to those by-products obtained by evaporating sulfite waste liquor, there are other valuable by-products obtainable by using other processes. The liquor may be fermented to produce ethyl alcohol; about 40 liters of alcohol can be produced per ton of dry solids. This process reduces the BOD of the liquor by utilizing the simple sugars alone. Acetone and butyl alcohol can also be produced from the waste, with an overall BOD reduction of about 82 per cent. However, in 1950, only one mill in the United States manufactured ethyl alcohol from sulfite waste liquor. The drawback of this process is that it costs more to manufacture alcohol from the sulfite waste liquor than it does to use blackstrap molasses or ethylene as raw materials.

Another product of fermenting the liquor is yeast for cattle feed. In 1948, a plant was built in Wisconsin to produce yeast fodder by this method, and the plant achieved a 60 to 70 per cent BOD reduction. Unfortunately, the market was found to be very limited, because of competition with brewers' yeast. Laboratory experiments have also been used to produce torula yeast for stock feed, with a resulting reduction of 40 per cent in BOD; 350 pounds of yeast are obtained from a ton of waste solids.

Recovery is also practiced in kraft mills. The black liquor (spent cooking liquor) is processed by evaporation and incineration, in order to recover chemicals, and to utilize the heating value of the dissolved wood substances. During the recovery process, Na_2SO_4, with or without added sulfur, is added to replace the relatively small proportion of chemicals lost in the various steps of the process. Following these additions and the incineration, the smelt is dissolved in water to form "green liquor". The chemical compounds in the green liquor are converted to the desired cooking chemicals by the addition of lime, resulting in the formation of "white liquor" and a lime mud consisting chiefly of $CaCO_3$. The white liquor is returned to the pulping operation as the cooking liquor, and the lime mud is calcined to form calcium oxide, which is reused in converting other green liquor to white liquor. By-product recovery of turpentine, resin, and fatty acids also aids in the reduction of strength of kraft waste-water effluents. Maximum recovery of these by-products may result in kraft effluents in which chemical toxicants are no longer a significant factor, insofar as stream pollution is concerned. The turpentine is recovered from the digester relief gases which also contain small quantities of $(CH_4)_2S$, dimethyl sulfide, methyl mercaptan, and ketones. The black liquor also contains recoverable quantities of sodium salts, rosin, and fatty acids which separate on concentration and cooking of the black liquor. This material is called "crude sulfate soap", and after it has been skimmed from the black liquor, it is treated with acid to form tall oil. The resin and fatty acids are further refined, and have a variety of applications in industry.

B. Suspended Solids Reduction

The suspended matter present in pulp and paper mill wastes, consists mainly of fibre, fibre debris, and filling and coating materials such as clays, calcium carbonate, and titranium dioxide. In most mills the bulk of these materials are captured from the machine waters by means of savealls and are returned to the system for reuse. The efficiency of these savealls depends upon the process employed and the nature of the solids they are expected to retain. Under some conditions, highly efficient devices of this kind can retain a sufficient quantity of the suspended solids content of the effluents so that further removal is not necessary. However, in many other instances, further treatment is necessary and the solids so collected are not suitable for reuse but must be disposed of. This is particularly true for mills that reclaim the fibre from used paper, as only a part of such stock is reclaimable by deinking processes. In these the fibre is freed of ink, filler, sizing materials, and fibre fines, all of which are not reclaimable.

The most common means for treating solids-bearing wastes in the paper industry is sedimentation, although in some plants flotation and filtration are used. Circular mechanically cleaned clarifiers predominate as the type of settling unit employed, followed by reactor-type clarifiers, rectangular mechanically cleaned basins, and conical tanks without collector mechanisms. Some of these are equipped with influent deaerating devices to prevent floating fibre from accumulating on the surface. Most of them have skimmers and some have integral mechanical flocculators. A few mills employ earth-embanked alternating basins to remove suspended solids from their effluents. In instances where a greater fraction of the total suspended solids must be removed than will settle normally, coagulants such as alum, activated silica, and polyelectrolytes are used to render the nonsettleable solids settleable.

In general, sedimentation without the addition of coagulants removes 70-80% of the total suspended solids from paper mill effluents. This percentage can be lower when highly efficient savealls are employed in the mill or when dispersing agents are present. The percentage may be higher when sizing materials such as alum, which tend to coagulate the solids, are used in the papermaking process. Coagulants can produce a total suspended solids reduction in excess of 90% when interfering substances such as those contained in cooking liquors are absent. Effluent quality produced from paper machine waters by plain sedimentation generally ranges from 1 to 2 lb. per 1000 gal. and, if coagulants are employed, from ½ to 1 lb. per 1000 gal. of effluent.

C. Sludge Disposal Techniques

The underflow from clarifiers treating pulp and paper mill effluents ranges in consistency from 2 to 12% solids depending on the nature of the solids settled out and the clarifier operation. It can be generally stated that the greater the percentage of inert suspended matter present, the thicker the underflow. However, the length, type, concentration, and degree of hydration of fibre present in the waste treated can all influence the density of the underflow. Some effluents, such as those containing groundwood fines or highly hydrated fibre, produce very thin underflows that are difficult to thicken and to remove from the clarifier in a concentration suitable for further dewatering and disposal. An active research program is being carried on by the industry to find means for dewatering these sludges. In some instances, flotation is employed to separate the more hydrous solids, since this process can generally produce thicker slurries. Underflows of under 5% solids concentration are generally moved by positive displacement or centrifugal pumps, and thicker flows are handled by screw impeller pumps. Secondary thickening is sometimes used where further dewatering prior to disposal is practised.

Some papermill sludges such as deinking sludge can be dewatered by vacuum filtration; others, such as most boardmill sludges, are resistant to filtration. Recently, horizontal conveyor-type centrifuges have come into use for dewatering some of the more difficult sludges, such as the sludge produced by clarification of fine papermill and boardmill effluents. Vacuum filtration produces cakes varying between 20 and 30% solids at rates from 5 to 20 dry lb./sq. ft/hr. Horizontal conveyor-type centrifugals can produce cakes up to 40% solids at feed rates as high as 4000 gal/hour with a recovery of 85% of the feed solids. In most plants, conditioning agents are not used, because most of the common ones are not effective in promoting dewatering. Recently, there has been interest in the use of polyelectrolytes for this purpose. Drying beds are used by some mills to dewater sludge. Some of these have underdrains while others are simply impoundments in which water separating from the solids is decanted and natural drying is allowed to take place. When the sludge becomes sufficiently dense, it is dug out mechanically and transported to a disposal area. Such basins are generally built in multiple so that cleaned sections will be available at all times.

Land disposal is almost universally used for final disposition of paper mill sludges. In some instances, the sludge is mixed with other materials for use as fill. If the concentration of nitrogenous sizing materials is low and the sludge is sufficiently dry, this practice does not give rise to an odor problem. Experiments with incineration and wet combustion have indicated that, for sludges high in ash, these methods are unsatisfactory and are excessive in cost because of the difficulty of dewatering to a sufficiently high degree to support combustion. Also, the quantity of sludge to be disposed of by many mills is too small to justify the high capital cost of incineration equipment and its operation.

D. BOD Reduction Methods

Stabilization Basins

Stabilization basins are the most widely used units for biological oxidation at pulp and paper mills. Most of these are located at mills where a large area of suitable land is available and a high ambient temperature is favorable to high microbial metabolic rates. Two types are presently is use, the natural reaeration variety and the mechanically aerated type. The natural reaeration basin is normally shallow but can be irregular in depth. Its design is based essentially on an air-exposed water surface, particularly when a high degree of BOD reduction is required. To produce a 90% BOD reduction, the BOD loading is maintained below 50 lb. per acre-ft. per day. It has been established that a reaeration coefficient, k_2, of 0.15 is suitable for basins with an average depth of 5 ft. In some instances, because of natural terrain and the fact that either long storage is available or a high percentage of BOD reduction is not necessary, deep stabilization basins have been constructed. Some of these serve a dual purpose, providing storage for discharge regulation in proportion to flow in the receiving stream.

Mechanically aerated basins have come into use in recent years for the purpose of raising oxidation rates and hence shortening the storage period required. Diffused air, low head recirculating pumps, and low dam and riffle systems have been tried, but the most common aeration device employed is the mechanical surface aerator. When adequately aerated, an oxidation rate of k = 0.1 at 20° C and k = 0.16 at 30°C is observed. Under these conditions, about 75% BOD reduction can be expected in 4 days detention and 90% in 7 days. Loadings can be carried as high as 400 lb. per acre-ft. per day, and are dependent on waste strength and the degree of aeration applied. If the nutrient elements, nitrogen and phosphorus, are in short supply in a specific waste, these reductions may be diminished somewhat, but it is doubtful that addition of these elements is justified as it is with the activated sludge process.

Requirements for successful design and operation together with the advantages and disadvantages of stabilization basins can be summarized as follows. These basins must receive a waste substantially free from settleable solids because, if allowed to accumulate, these liquefy on decomposition and add to the BOD loading. For this reason, it is often practical to build a small entrance basin that can be cleaned periodically, between the effluent clarification system and the major stabilizing system, to trap suspended matter overflowing the clarifier during periods of upset. The stabilization basins themselves are best built in multiple to prevent short circuiting. At least two separate basins should be used, or one or more dividing walls provided if a single basin is employed. All dikes should be built properly on the basis of soil conditions and provided with core walls where necessary. Basins should be cleared of stumps, and the bottom should be compacted or sealed if this appears necessary. Inlet and outlet structures should be designed to provide for varying the water level for mosquito control. Stabilization basins have distinct advantages over mechanical oxidation systems in that they are not subject to process upset, can absorb variations in loading, require little attention, and involve little operating cost. The greatest shortcomings are the high land requirement, particularly with non-aerated basins, and the fact that color is not removed from the effluent. Odor, from either aerated or non-aerated stabilization basins, is no problem when kraft mill effluents are treated. However, when certain other effluents such as boardmill wastes are treated, a high degree of aeration must be provided to prevent formation of odorous gases.

Trickling Filters

Many attempts have been made to apply trickling filters to the treatment of pulp and paper mill wastes. Experiments have indicated that filters using stone media are costly and are not satisfactory for general application in that they cannot provide a high degree of purification at high loading rates and they are subject to clogging with fibre. In 1965, stone trickling filters were in use in only two small mills in Canada and the U.S.A.

Plastic media have been employed in trickling filters providing partial purification of pulp mill effluents (40-60% BOD reduction) since they largely eliminate the media-clogging problem and can be operated at high hydraulic loadings. By 1965, two large installations were put into operation at two American kraft mills. There is also interest in filters using these media for pretreatment and cooling of hot effluents, prior to the application of other methods of oxidation.

Performance tests with the plastic media indicated that, at loadings of 100-800 lb./1000 cu. ft., the BOD reduction averaged about 45% and remained constant irrespective of loading when treating unbleached kraft mill effluent having an initial BOD between 250 and 400 mg/liter.

Removals as high as 370 lb. of BOD/1000 cu.ft. were observed at hydraulic loadings of 175 mgd/acre. An example of the relationship of BOD loading to reduction is shown in Table X.

Table X. BOD loading versus BOD reduction, for plastic media trickling filters.

Applied BOD (lb./1000 cu.ft. of media/day)	Removed BOD (lb./1000 cu.ft. of media/day)
200	100
300	130
400	175
500	220
600	270
700	310
800	370

From these data, the ability of the filter to remove a large quantity of BOD at high application rates is obvious. Hence, it appears that the future application of such filters lies in the area of "roughing" treatment and waste precooling. The operating cost is somewhat lower than that for activated sludge treatment since less power is generally required for waste recycle than for aeration. Nutrient addition is necessary for good filter performance.

Activated Sludge Treatment

In 1948, experimentation was started to determine if the activated sludge process could be applied for reducing the BOD of kraft mill effluents. Laboratory trials indicated that these effluents could be oxidized to a high degree by the process if good internal mill control of waste strength and alkalinity was practised and nutrients in the form of ammonia and phosphates were added. Two exhaustive pilot plant studies dealing with unbleached and bleached kraft effluent followed. The conclusions arrived at were similar to the laboratory findings. Shortly thereafter, a large unit was built at one American pulp mill where the process worked successfully, producing BOD reductions of 80-90% and about a 30% color reduction. Bioassay tests indicated that the effluent produced was not toxic to fish life. Oxidation rates in excess of 100 lb. of BOD/1000 cu.ft. of aerator capacity could be obtained due to the relatively high temperature of the effluents and the availability of wood hydrolysis products present in the waste as microbial food.

Following the adaptation of this process to kraft effluents, pilot studies with other wastes from the production of pulp and paper products were conducted by the industry. These included paperboard, roofing felt, neutral sulfite pulping, and deinking effluents. These wastes could also be oxidized to a high degree. As of 1965, 12 full-scale plants have been put into operation at mills. Six of these treat kraft effluent, 4 boardmill, 1 deinking, and 1 roofing felt waste, amounting to a total of over 100 mgd. Another 10-20 mgd. is treated in municipal activated sludge plants in combination with sanitary sewage.

Two modifications of the basic activated sludge flowsheet are in use. In the contact stabilization system, aeration periods employed for the mixed liquor are shorter than normal and the return sludge is aerated for a substantial period. It is claimed that capital cost can be somewhat reduced by this modification and that a reservoir of active sludge is maintained against possible damage to the mixed liquor sludge by shock loads. The other modification is the so-called "dynamic" system in which aeration, sludge separation, and sludge return are incorporated in a single unit. This arrangement promotes improved conditions, since the return sludge does not have to be pumped and is returned in fresh condition to the waste undergoing treatment. Because there is a greater degree of sensitivity inherent to this arrangement than to the conventional process, hydraulic design capacity, particularly of the settling sections of such units, should be conservative.

The activated sludge process is generally applied where sufficient and suitable land is not available for stabilization basins and where the degree of oxidation of the waste needs to be high. The waste to be treated must be free from mineral acidity or caustic alkalinity, the temperature should preferably be below 110°C, and the volatile suspended solids content should average no higher than 1 lb/1000 gal. Requirements for added nutrient are generally somewhat less than the theoretical optimum of 1 mg/liter of nitrogen to 20 mg/liter of BOD and 1 mg/liter of phosphorus to 60 mg/liter of BOD, because of the presence of traces of these elements in most effluents.

Although successful in treating most pulp and paper mill effluents and combinations thereof, the activated sludge process has some serious shortcomings. The capital cost is high, ranging from $80,000 to $100,000 per mgd.of capacity (in 1965) depending on size, and exclusive of pre-treatment for reduction of the suspended solids content of the waste. Removal of color, while generally measurable, is not effected to a high degree when treating pulping and bleaching wastes. The waste activated sludge produced compacts poorly and is extremely resistant to dewatering; hence, it presents a difficult disposal problem. At present, it is vacuum filtered where a large quantity of primary sludge is available to absorb it.

In other cases, it is disposed of on the land together with fly ash. Another shortcoming to the use of this process is that wastes having a BOD approaching 3000 mg/liter cannot be treated because of the oxygen exchange limitation. There is also the fact that its sensitivity to surges in waste load requires careful control and frequently considerable in-mill sewer rearrangement for the process to operate satisfactorily. Experimental work now in progress indicates that partial pretreatment in a roughing filter containing plastic media may do much to stabilize the process reaction to surges in loading. Experimental evidence has also been obtained indicating that treatment of a fraction of the total effluent by this process, followed by recombination with the remaining waste flow, stimulates further oxidation of the total waste in stabilization basins and thus shortens the storage period required for a given degree of oxidation.

E. Land Disposal by Irrigation and Seepage

A recent survey of the pulp and paper industry in the U.S.A. revealed that 26 mills are experimenting with or are practicing effluent disposal by irrigation or soil seepage. Seventeen of these are full-scale operations, of which 9 are spray units, 1 is flood irrigation, and the remainder are either seepage ponds or ditch-type irrigation. The majority of the systems are seasonal operations tailored to cope with low stream flow conditions occurring during the warm weather period. The exceptions are one spray system and two seepage basins which are operated the year round. The recent trend has been toward the disposal of weak wastes by irrigation, rather than the disposal of strong wastes by soil seepage. All of the 6 most recent full-scale installations are designed for irrigation, 5 being by spray application and the remaining 1 by ridge-and-furrow distribution. Several factors have contributed to this trend toward accepting the principles of irrigation in contrast to depending upon seepage through porous soils. Foremost is the general scarcity of soils suitable for high rate seepage installations at most mills. Unless an extremely porous soil is available, the land requirement becomes large and the distribution problem serious and costly. Vegetation, by increasing soil porosity and evaporating considerable water through transpiration, reduces greatly the land area requirement.

Like all methods of effluent disposal, irrigation has both advantages and disadvantages. At best, land requirements are high, since for most soils 40-50 acres are required per mgd. of effluent. This, however, is of no disadvantage for certain mills located in agricultural areas where the effluent is used to supplement existing irrigation water. The limitation does restrict use of irrigation either to relatively small mills or for disposal of specific effluents of relatively low volume. BOD loading generally must be maintained below 200 lb. per acre per day to maintain the soil in aerobic condition. The pH should not be below 6.0 or above 9.0, and the sodium adsorption ratio should be less than 8.0. There is no evidence that the disposition of salt-bearing effluents from pulp and paper making operations differs substantially from irrigation with water of like salt content.

Isolated cases of groundwater contamination have occurred in areas where pulping liquors were applied to the soil. In all known cases the soil was highly porous sand, allowing rapid transit of effluent to the water table and creating a high concentration of effluent in a localized area. Since the potential for groundwater contamination does exist when highly colored effluents are applied to the soil, individual site evaluation for soil type, direction of groundwater movement, and location of existing wells must be made. It does not appear, from present knowledge, that problems of groundwater contamination are likely to occur in land disposal operations related to irrigation on moderate and heavy textured soils employing effluents other than pulping liquors. With pulping liquors, hydraulic loadings are limited and the dilution afforded upon reaching the groundwater table is substantially greater than the dilution that occurs in high-rate percolation through porous soil.

As many mills are located on streams which exhibit a well defined low flow pattern of short duration, the effluent disposal problem is seasonal. Except for some streams in the Rocky Mountain area fed by melting snow, this low-flow period coincides with seasonal demands for irrigation water and is generally of short duration. Hence, there is a potential for tailoring a waste disposal program either to the increased demands for irrigation water during this period or to disposal on the land when evaporation and evapotranspiration rates are greatest.

Although well suited to reasonably level land and warm weather application, irrigation disposal exhibits some disadvantages in hilly terrain or where effluent treatment is required the year round in freezing climates. In hilly terrain, the potential for runoff at high hydraulic loadings exists, which may increase the land requirements; and freezing temperatures may include excessive ice buildup in the sprayed area or other problems attendant with handling liquids in lines that are taken out of operation during periods of freezing temperatures.

The operating cost of land disposal compares favorably with other methods of secondary treatment and may represent a substantial saving in capital investment. Added advantages over other methods are that BOD reduction may approach 100% and performance is uniform. The pumping cost for spray irrigation systems is generally less than the power requirement of biological treatment processes.

Land disposal does not have the potential of wholesale application as a treatment method in the industry. In some instances, however, it does offer an economically attractive means of solving some of the waste disposal problems of the industry where small waste volumes are involved. The land requirements for disposal of the total mill effluent from pulp mills are great enough that integration of waste disposal with a productive agricultural program is indicated.

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PULP AND PAPER MILL POLLUTION IN NEWFOUNDLAND

The final section of this report contains a detailed discussion of the existing pollution problems at the two operating Newfoundland mills, Price Newfoundland Limited, Grand Falls, and Bowaters Newfoundland Limited, Corner Brook. It also contains a summary of all available information concerning two proposed mills, Javelin Pulp and Paper Company Limited, to be located in Stephenville and Newfoundland Pulp and Chemical Company Limited, to be located in Come-by-Chance. In examining the pollution situation associated with each existing mill, the following topics are discussed in detail:

(1) Water Supply and Water Use

(2) The Manufacturing Process

(3) Mill Wastes

(4) Waste Treatment Facilities

(5) Effluent Analysis

(6) Effects of Mill Wastes on the Receiving Waters

Similar topics are also discussed regarding the two proposed mills at Stephenville and Come-by-Chance. However, it should be noted that the information concerning the proposed mills is based on predictions supplied by the individual mills, when these mills were in the preliminary design stage. Also included are the writer's comments concerning the probable validity of the data provided by the mills. Future correspondence from the mills concerned may lead to significant changes in the design data presented in this report.

BOWATERS NEWFOUNDLAND LIMITED

Introduction

Bowaters Newfoundland Limited pulp and paper mill, located in the city of Corner Brook, began production in 1925. At the present time, the mill produces approximately 1,100 tons of newsprint per day. This newsprint is made from a 3:1 mixture of groundwood to sulfite pulp. Consequently, the daily production of groundwood and sulfite pulp approximates 825 tons and 275 tons respectively. In September 1968, the mill changed over from a calcium to a sodium base sulfite process. The sodium base process increased pulp yield to 52-54% of the wood processed from the 48% yield obtained with the calcium base process. No other significant process changes have occurred during the period from September 1968 to April 1970.

Water Supply and Water Use

Process water for mill operations is obtained from the Corner Brook River and amounts to approximately 36.5 million U.S. gallons per day. This water is screened for the removal of coarse suspended solids and chlorinated for slime control prior to its use within the plant. Water required for drinking and sanitary purposes is supplied by the city of Corner Brook. A breakdown of the water requirement for various plant operations appears in Table XI.

Table XI. Water required for various mill operations, Bowaters.

Mill Operation	Water Requirement (m.g.d.)
Wood processing	7.0
Sulfite mill	18.25
Groundwood mill	1.75
Paper mill	9.5

The Manufacturing Process

The manufacturing processes employed by Bowaters are typical of those found in newsprint manufacturing throughout the industry. A description of sulfite and groundwood pulping and of wood processing and paper mill operations was presented in Part I of this report and will not be repeated here. However, it should be noted that bleaching of the groundwood pulp is used when required. The bleaching agent commonly used is zinc hydrosulfite.

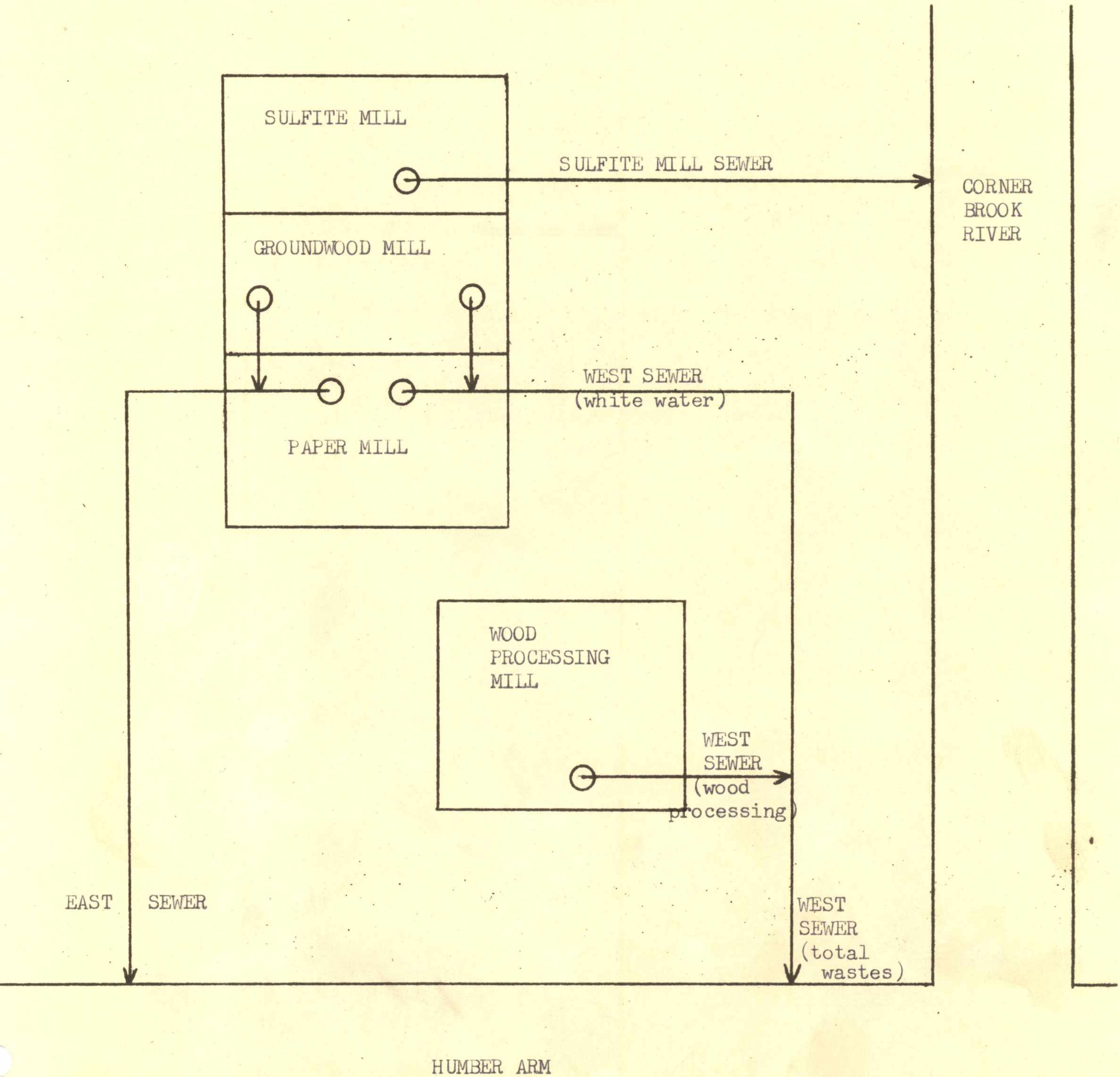
Mill Wastes

Wastes from the various mill operations are discharged to the Humber Arm via three main sewers, namely, the sulfite mill sewer, the west sewer, and the east sewer, as shown in Figure V. All wastes from the wood processing operation and approximately 52% of the white water wastes originating in groundwood mill and paper mill make up the total flow in the west sewer. The east sewer is used to discharge the remaining 48% of the white water wastes from the groundwood mill and paper mill. The average daily discharge of each of the waste streams is presented in Table XII.

Table XII. Approximate discharge volume of the waste streams, Bowaters.

Waste Stream	Stream No.	Discharge (m.g.d.)
Sulfite mill sewer	1	18.25
West sewer, white water	2	5.85
West sewer, wood processing	3	7.00
West sewer, total wastes	4	12.85
East sewer	5	5.40

FIGURE 5. Overall layout, Bowaters Newfoundland Limited, Corner Brook.



Existing Waste Treatment Facilities

No actual external waste treatment facilities as such are employed at the Bowaters mill although a bark recovery system put into operation in 1965 greatly reduces the amount of suspended solids wasted from the wood processing operation. In the bark recovery system, screens are used to remove the bark from the waste stream. The bark then passes through a drier and shredder before entering the boiler room where it is burned to produce heat energy. The bark recovery system is actually a profitable operation to Bowaters, as the value of heat energy obtained by burning the bark is greater than the cost of operating and maintaining the recovery system.

The Humber Arm

Of prime importance to this Department is the effect of mill wastes on the fish life of the Humber Arm. Preliminary surveys of the Humber Arm were conducted by biologist Mascaluk in October 1968 and October 1969. A brief summary of Mr. Mascaluk's findings will be presented at this time. Water samples, collected from various locations in the Humber Arm were analysed for salinity, temperature, dissolved oxygen, pH, biochemical oxygen demand, turbidity and sulfite waste liquor. Sediment samples were collected at various points using a modified Petersen dredge. The survey revealed that large deposits of decomposing wood, bark and fibre existed in certain areas of the Humber Arm. In the surface water layer, dissolved oxygen saturation values were found to be lowest in the area of the mill and increased as the distance from the mill increased. At no time during this survey were the D.O. values obtained below the 5.0 ppm critical to fish life. For more detailed information of the Humber Arm survey, Mr. Mascaluk's report should be consulted.

Effluent Analysis Program

Eight-hour composite effluent samples of the various Bowaters' sewers were collected periodically between October 1968 and April 1970. The samples were collected by Bowaters' personnel and shipped to the Department (St.John's laboratory) for analysis. The samples were analyzed for pH, B.O.D., suspended solids and total solids. A summation of the results of the chemical analyses for the mill sewers appears in Table XIII, while the complete data for the various sewers appears in Tables XIV to XVIII.

Table XIII. Average concentration and loadings of waste contaminants in Bowaters sewer 1968-1970.

Sewer	Year	pH range	B.O.D.		Suspended Solids		Total Solids	
			ppm.	tons/day	ppm.	tons/day	ppm.	tons/day
Sulfite Mill	1968	3.6-4.6	837	62.4	104	7.7	4296	320.5
West (total wastes)	1968	6.2-7.0	202	10.6	499	26.1	671	34.1
East	1968	6.1-7.0	257	5.7	435	9.7	813	18.0
Total Discharge tons/day				78.7		43.5		372.6
Sulfite Mill	1969	3.8-4.5	536	40.0	72	5.4		
West (total wastes)	1969	6.5-7.0	215	11.2	429	22.4		
East	1969	6.4-7.0	259	5.7	345	7.6		
Total discharge tons/day				56.9		35.4		
Sulfite Mill	1970	4.00-4.82	827	61.7	105	7.8	4980	371.5
West (total wastes)	1970	6.20-7.05	266	13.9	695	36.3	1090	56.9
East	1970	6.37-6.98	212	4.7	237	5.3	621	13.8
Total Discharge tons/day				80.3		49.4		442.2

Table XIII. (continued)

Sewer	Year	pH Range	B.O.D.		Suspended Solids		Total Solids	
			ppm.	tons/day	ppm.	tons/day	ppm.	tons/day
Sulfite Mill	Overall Average 1968-1970	3.6-4.82	749	56.0	97	7.2	4638	346.0
West (total wastes)	"	6.20-7.05	229	12.0	556	29.1	881	45.5
East	"	6.1-7.0	240	5.3	338	7.5	717	15.9
Total Discharge tons/day				73.3		43.8		407.4

Salient Points

(1) During the early years of operating the mill, most of the logs supplied to the mill were floated down the Humber River and across the Humber Arm to the mill site. During the transporting operation, many logs escaped and eventually sank in the Humber River and Humber Arm. These logs contribute a large amount to the bottom deposits in the Humber Arm. In recent years, most logs have been transported to the mill by truck, and by rail, thus minimizing but not eliminating the deposition of logs in the Humber Arm.

(2) On several occasions, the writer observed the bark recovery system at Bowaters in operation. It was found that the system, when operating, is very efficient. However, due to mechanical problems, this system is shut down a considerable amount of the time. Also the detection of a piece of metal in the conveyor belt used to carry the bark to the dryer reversing and re-depositing the bark in the sewer and eventually in the Humber Arm.

Table XIV. Sulfite mill sewer analysis, Bowaters, 1968-1970.

Date	Year	pH	B.O.D. ppm.	Suspended Solids ppm.	Total Solids ppm.
Oct.9	1968	4.5		90	5200
Oct.15		4.3	1110	116	4813
Oct.22		3.6	800	165	4923
Oct.29		4.0	880	60	3595
Nov. 5		4.3	1010	98	5543
Nov.12		4.1	1060	80	5163
Nov.19		3.9	637	105	4835
Nov.26		4.0		94	2802
Dec. 3		4.6	633	78	3508
Dec.10		4.3	704	202	3690
Dec.17		4.2	697	48	3183
Jan.15	1969	3.9	570	47	
Jan.16		4.5	485	53	
Jan.17		3.8	619	66	
Jan.21		4.3	537	102	
Feb. 6		4.3	608	85	
Feb.18		4.4	503	71	
Mar. 4		4.0	427	81	
Jan.13	1970	4.45	647	33.0	5612.0
Jan.20		4.58	690	126.0	4986.0
Jan.27		4.60	695	94.0	3854.0
Feb. 3		4.47	720	100.0	4454.0
Feb.10		4.66	560	34.0	3998.0
Feb.17		4.71		75.0	4652.0
Feb.24		4.82	760	54.0	4402.0
Mar.13		4.35		67.0	4590.0
Mar.10		4.40	770	55.0	4178.0
Mar.17		4.30	1330	419.0	7040.0
Mar.24		4.00	1270	94.0	7016.0

Table XV. West sewer, white water analysis, Bowaters, 1968-1970.

Date	Year	pH	B.O.D. ppm.	Suspended Solids ppm.	Total Solids ppm.
Oct.9	1968	6.7		440	580
Oct.15		6.9	153	388	573
Oct.22		6.6	186	708	925
Oct.29		6.7	228	478	625
Nov. 5		6.7	244	793	1130
Nov.12		6.9	200	278	480
Nov.19		6.5	177	685	835
Nov.26		6.5		588	744
Dec. 3		6.6	122	478	620
Dec.10		6.9	137	760	965
Dec.17		6.9	123	625	818
Jan.15	1969	6.6	217	536	
Jan.16		6.6	132	200	
Jan.17		6.7	175	407	
Jan.21		6.9	100	360	
Feb. 6		6.5	226	462	
Feb.18		6.9	179	321	
Mar. 4		6.7	199	349	
Jan.13	1970	6.85	155	549	898
Jan.20		6.76	174	528	940
Jan.27		6.95	185	469	774
Feb. 3		6.65	185	470	792
Feb.10		7.04	134	457	742
Feb.17		7.35		439	686
Feb.24		7.32	122	288	636
Mar. 3		6.83		72	482
Mar.10		6.95	127	223	452
Mar.17		6.43	209	192	1117
Mar.24		6.46	206	404	982

Table XVI. West sewer, wood processing analysis, Bowaters, 1968-1970.

Date	Year	pH	B.O.D. ppm.	Suspended Solids ppm.	Total Solids ppm.
Oct. 9	1968	6.6		490	680
Oct.15		6.1	248	880	1258
Oct.22		6.6	288	700	1083
Oct.29		6.2	211	465	783
Nov. 5		6.3	396	1138	1328
Nov.12		6.2	315	498	875
Nov.19		6.1	245	600	813
Nov.26		6.3		255	313
Dec. 3		6.8	125	160	300
Dec.10		6.6	193	380	548
Dec.17		6.5	209	938	1040
Jan.15	1969	6.4	250	502	
Jan.16		6.8	342	568	
Jan.17		6.2	298	612	
Jan.21		6.8	276	412	
Feb. 6		6.8	180	616	
Feb.18		6.7	341	865	
Mar. 4		6.6	168	256	
Jan.13	1970	6.80	233	595	980
Jan.20		6.52	340	777	1194
Jan.27		6.60	373	1519	1760
Feb. 3		6.50	403	639	1112
Feb.10		6.80	660	544	998
Feb.17		6.96		1084	1304
Feb.24		6.77	310	648	937
Mar. 3		6.62		308	672
Mar.10		6.35	358	585	1308
Mar.17		5.70	385	713	1296
Mar.24		6.42	281	592	754

Table XVII. West sewer, total wastes analysis, Bowaters, 1968-1970.

Date	Year	pH	B.O.D. ppm.	Suspended Solids ppm.	Total Solids ppm.
Oct. 9	1968	6.6		350	520
Oct.15		6.4	208	573	718
Oct.22		6.5	178	765	898
Oct.29		6.5	238	393	635
Nov. 5		6.7	247	665	885
Nov.12		6.6	270	478	560
Nov.19		6.5	177	593	763
Nov.26		6.2		268	445
Dec. 3		6.8	172	503	695
Dec.10		6.7	177	453	620
Dec.17		7.0	154	448	638
Jan.15	1969	6.6	270	549	
Jan.16		6.7	237	308	
Jan.17		7.0	243	327	
Jan.21		6.5	182	398	
Feb. 6		6.8	194	449	
Feb.18		6.8	208	603	
Mar. 4		6.7	171	368	
Jan.13	1970	7.05	165.0	420.0	972.0
Jan.20		6.73	267.0	583.0	884.0
Jan.27		6.70	378.0	1118.0	1440.0
Feb. 3		6.70	263.0	485.0	950.0
Feb.10		7.02	177.0	441.0	738.0
Feb.17		6.90		781.0	1134.0
Feb.24		6.85	258.0	737.0	1032.0
Mar. 3		6.48		620.0	638.0
Mar.10		6.20	358.0	1134.0	1715.0
Mar.17		6.51	295.0	738.0	1154.0
Mar.24		6.62	231.0	588.0	1332.0

Table XVIII. East sewer analysis, Bowaters, 1968-1970.

Date	Year	pH	B.O.D. ppm.	Suspended Solids ppm.	Total Solids ppm.
Oct. 9	1968	7.0		260	580
Oct.15		6.4	240	748	1035
Oct.22		6.6	265	275	668
Oct.29		6.6	299	655	1018
Nov. 5		7.0	283	285	578
Nov.12		6.7	220	270	555
Nov.19		6.8	255	390	925
Nov.26		6.1		593	873
Dec. 3		6.7	267	505	1115
Dec.10		6.7	243	430	825
Dec.17		6.8	237	370	765
Jan.15	1969	6.6	265	351	
Jan.16		6.4	286	330	
Jan.17		6.6	331	439	
Jan.21		7.0	184	279	
Feb. 6		6.8	168	278	
Feb.18		6.6	308	311	
Mar. 4		6.8	272	424	
Jan.13	1970	6.98	146	206.0	624.0
Jan.20		6.70	235	250.0	694.0
Jan.27		6.89	118	186.0	414.0
Feb. 3		6.56	218	161.0	526.0
Feb.10		6.82	265	378.0	858.0
Feb.17		6.85		125.0	368.0
Feb.24		6.80	169	525.0	884.0
Mar. 3				126.0	424.0
Mar.10		6.65	271	145.0	578.0
Mar.17		6.60	277	284.0	869.0
Mar.24		6.37	211	216.0	588.0

(3) The sampling program revealed that the average suspended solids concentration in the wood processing sewer is 633 ppm. This indicates that, despite the bark recovery system, approximately 18 tons/day of bark are being discharged into Humber Arm. It should be noted that the 18 tons/day figure is definitely a minimum, as a large amount of the bark being discharged is too big in size to fit into a sample bottle. The actual bark discharge could quite easily be twice the amount measured during the sampling program.

(4) Bowaters are presently in the process of converting from sodium base sulfite pulping to a new high yield sodium base sulfite pulping process. It is expected that the new process will be ready for operation by September 1970. High yield sulfite pulping is extremely economical from Bowaters point of view and from this Department's standpoint, this process change should bring about a significant reduction in the pollutants discharged to Humber Arm via the sulfite mill sewer. A significant reduction in total solids and B.O.D. is expected when this new process is put into operation. However, the extent of the total solids and B.O.D. reduction cannot be estimated at this time. A comparison of the characteristics of the two sulfite pulping processes appears in Table XIX.

(5) Should external waste treatment facilities of any kind be required at the Bowaters pulp and paper mill, the construction of such facilities would be limited by the small area of land available in the vicinity of the mill. There is,however,adequate land available for the construction of primary treatment facilities.

(6) The measured suspended solids discharge, 43.8 tons/day, is approximately 4% of production.

(7) Bowaters recently allotted $500,000.00 to be spent on pollution control over the next five years.

Table XIX. Characteristics of sodium base sulfite pulping and high yield sodium base sulfite pulping.

	High yield sodium base sulfite pulping.	Regular sodium base sulfite pulping.
Pulp	Lower quality, adequate for newsprint	High quality pulp
Pulp yield production	70% of wood processed	50-55% of wood processed
Lignin	Part of lignins present in wood are incorporated in the fibre produced	All lignins are broken down and become a parto of the SWL and are then discharged to the receiving waters
Cellulose	No cellulose breakdown	Some of the cellulose is broken down and discharged to the receiving waters with the SWL
Digestion time	6 hours	$7\frac{1}{2}$ hours
Digestion temperature	10° lower than for regular sodium base sulfite pulping	
Pollution	Less waste materials produced; therefore, less waste discharge to receiving waters	

Conclusions and Recommendations

Through the sampling program, it has been determined that the Bowaters pulp and paper mill are discharging 73.3 tons/day of B.O.D., 43.8 tons/day suspended solids and 407.4 tons/day total solids. The change from sodium base sulfite pulping to high yield sodium base sulfite pulping will bring about a significant reduction in the total solids and B.O.D. discharge. Preliminary surveys of the Humber Arm have indicated that the suspended solids rather than the B.O.D. in the wastes may be the major problem. Dissolved oxygen measurements in the Humber Arm have shown that the dissolved oxygen present is adequate to maintain normal fish life. However, sludge deposits consisting of bark and fibre in the Humber Arm have undoubtedly destroyed bottom fauna.

It is recommended that a detailed survey of the Humber Arm be undertaken to determine the magnitude of the pollution problem. Monitoring of the sulfite mill sewer following the changeover to the high yield pulping process will indicate the reduction in pollution resulting from this process change. This Department must keep in close contact with Bowaters in order to maintain the interest that Bowaters have recently shown in their pollution problems. Finally, this Department should begin negotiations with Bowaters with the prime objective being a reduction in the suspended solids presently being discharged to Humber Arm.

PRICE NEWFOUNDLAND LIMITED

Introduction

Price Newfoundland Limited pulp and paper mill, located in the town of Grand Falls, was put into operation in 1909. At the present time, the mill produces approximately 900 tons of newsprint per day. This newsprint is made from a 3:1 mixture of groundwood to sulfite pulp. Consequently, 675 tons of groundwood pulp and 225 tons of sulfite pulp are produced daily. In 1966, the mill changed from calcium base to sodium base sulfite pulping. Since that time, no other significant process changes have occurred.

Water Supply and Water Use

Process water for mill operations is obtained from the Exploits River and amounts to approximately 79.2 million U.S. gallons per day. This water is screened for the removal of coarse suspended solids prior to its use within the mill. Water required for drinking and sanitary purposes is supplied by the town of Grand Falls. A breakdown of the water requirement for various plant operations appears in Table XX.

Table XX. Water required for various mill operations, Price Newfoundland Limited.

Mill Operation	Water Requirement (m.g.d.)
Woodroom	7.2
Sulfite mill	57.6
Groundwood mill and paper mill	14.4

The Manufacturing Process

The manufacturing processes employed by Price are typical of those found in newsprint manufacturing throughout the industry. A description of sulfite and groundwood pulping and of wood processing and paper mill operations was presented in Part I of this report and will not be repeated here. However, it should be noted that bleaching of the groundwood pulp is used when required. The bleaching agent commonly used is zinc hydrosulfite.

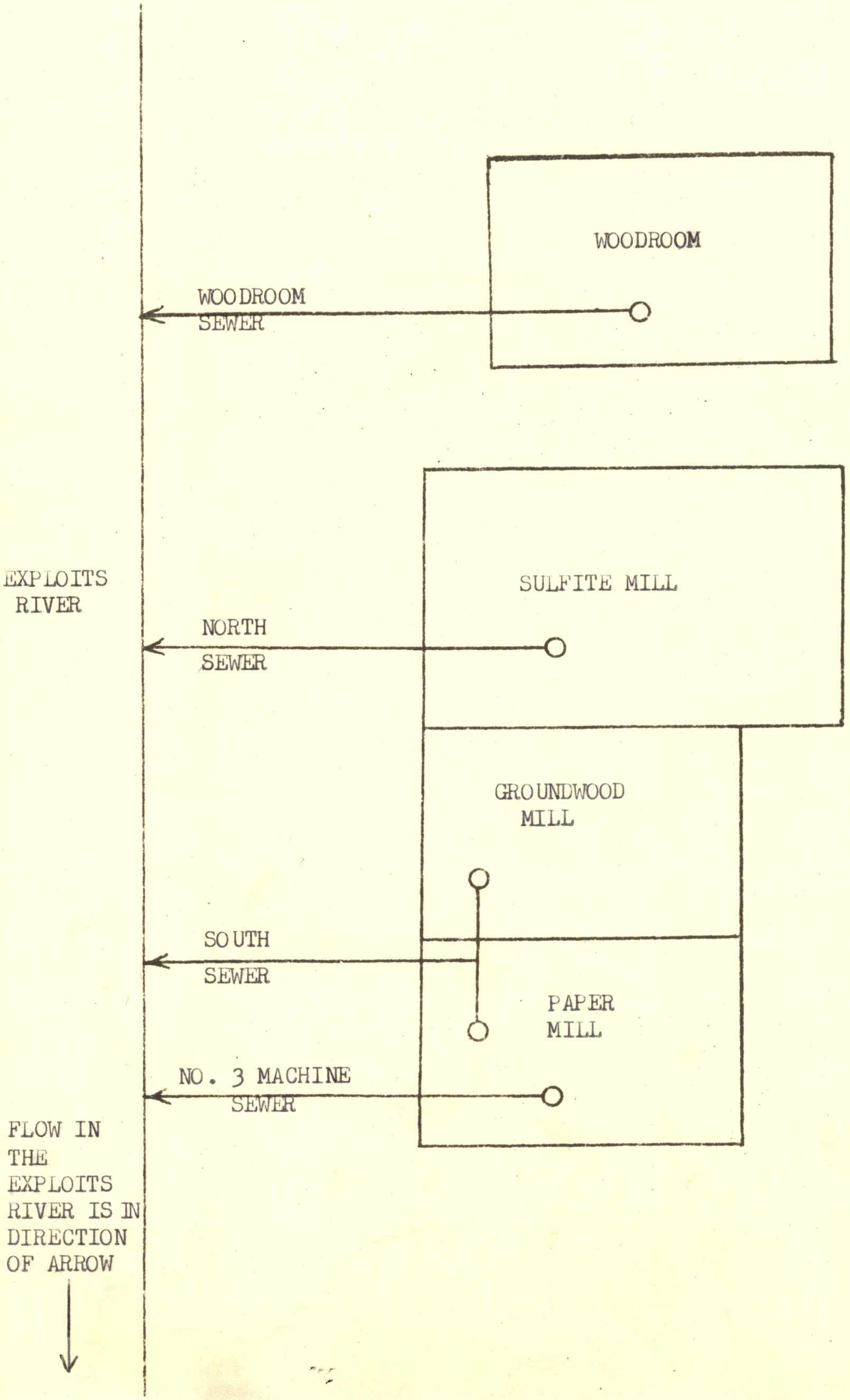
Mill Wastes

Wastes from the various mill operations are discharged untreated to the Exploits River downstream from the mill water intake line. Four main sewers, namely, the north sewer, the south sewer, woodroom sewer and No. 3 machine sewer are used for waste disposal (Figure 6). All wastes from the sulfite mill are discharged to the Exploits River via the north sewer. The south sewer is used for the disposal of groundwood mill wastes and approximately 50% of the paper mill wastes. The remaining paper mill wastes are discharged to the Exploits River via the No. 3 machine sewer. All woodroom wastes are discharged to the Exploits River via the woodroom sewer. The average daily discharge of each of the waste streams is presented in Table XXI.

Table XXI. Average daily discharge of waste streams, Price Newfoundland Ltd.

Waste Stream	Stream No.	Discharge (m.g.d.)
North sewer	1	57.6
South sewer	2	10.1
No. 3 machine sewer	3	4.3
Woodroom sewer	4	7.2

Figure 6. Overall layout, Price Newfoundland Limited, Grand Falls.



Existing Waste Treatment Facilities

At present, no actual external waste treatment facilities are employed at the Price mill, although bark recovery is practiced. In the bark recovery system, screens are used to remove the bark from the waste stream. The bark then passes through a drier and shredder before entering the boiler where it is burned to produce heat energy. The bark recovery system employed at Price is both old and inefficient.

Effluent Analysis Program

Twenty-four hour composite samples of the various Price sewers were collected periodically between May 1969 and April 1970. The samples were collected by Price personnel and shipped to the Department (St. John's laboratory) for analysis. The samples were analyzed for pH, B.O.D., suspended solids and total solids. A summation of the results of the chemical analyses for the mill sewers appears in Table XXII, while the complete data for the various sewers appears in Tables XXIII to XXVI.

The Exploits River and the Bay of Exploits

Untreated wastes from the Price mill are discharged to the Exploits River at a point 17.1 miles upstream of the Bay of Exploits. The mill wastes have a B.O.D. loading of 86.3 tons/day. Hence, the dissolved oxygen values in the Exploits River have been a primary concern of this Department. On many occasions during the past six years, surveys were conducted to determine the dissolved oxygen concentrations in the river at various locations downstream of the mill. Generally speaking, these surveys revealed that the dissolved oxygen content of the river, even in warm summer months has, in the past, been adequate

Table XXII. Average concentration and loadings of waste contaminants in Price sewers 1969 and 1970 and overall average 1969-1970.

Sewer	Year	pH range	B.O.D.		Suspended Solids		Total Solids	
			ppm.	tons/day	ppm.	tons/day	ppm.	tons/day
North	1969	3.4-4.4	280	65.9	162	38.1	2130	500.6
South	1969	5.9-6.4	99	4.1	209	8.6	383	15.7
No. 3 machine	1969	6.0-6.5	234	4.1	697	12.3	1008	17.7
Woodroom	1969	5.2-6.3	136	4.0	532	15.6	714	20.8
Total discharge tons/day				78.1		74.6		554.8
North	1970	3.40-4.10	345	81.1	158	37.1	1931	453.8
South	1970	5.74-6.40	103	4.2	255	10.5	400	16.4
No. 3 machine	1970	6.02-6.35	244	4.3	448	7.9	767	13.5
Woodroom	1970	5.10-6.10	165	4.8	313	9.2	494	14.5
Total discharge tons/day				94.4		64.7		498.2
North	Overall average 1969-1970	3.4-4.4	313	73.5	160	37.6	2031	477.2
South	"	5.74-6.4	101	4.2	232	9.6	392	16.1
No. 3 machine	"	6.0-6.5	239	4.2	573	10.1	888	15.6
Woodroom	"	5.10-6.3	151	4.4	423	12.4	604	17.7
Total discharge tons/day				86.3		69.7		526.6

Table XXIII. North sewer analysis, Price Newfoundland, 1969-1970.

Date	Year	pH	B.O.D. ppm.	Suspended Solids ppm.	Total Solids ppm.
May 6	1969	3.8	220		
May 13		3.6	317		
May 20		3.7	249		
May 27		3.4	288		
Sept. 19		4.1	217	121	1974
Sept. 28		4.4	195	211	1738
Sept. 30		3.4	287	136	2182
Oct. 1		4.2	397	455	3454
Oct. 22		4.4	264	47	1554
Oct. 29		4.3	265	178	3130
Nov. 5		3.8	233	115	1656
Nov. 12		3.8	383	49	1868
Dec. 9		3.7	309	197	2032
Dec. 16		3.8	298	110	1712
Jan. 27	1970	4.10	467	171.0	2658.0
Feb. 3		3.40	196	552.0	1718.0
Feb. 10		3.65	370	127.0	2076.0
Feb. 17		3.85		120.0	2076.0
Feb. 24		3.95	295	80.0	1906.0
Mar. 3		3.42	392	132.0	1724.0
Mar. 10		4.05	396	121.0	1884.0
Mar. 17		3.86	367	112.0	1707.0
Mar. 24		4.10	277	5.0	1630.0

Table XXIV. South sewer analysis, Price Newfoundland, 1969-1970.

Date	Year	pH	B.O.D. ppm.	Suspended Solids ppm.	Total Solids ppm.
May 6	1969	6.0	112		
May 13		6.1	107		
May 20		6.4	74		
May 27		6.0	131		
Sept.19		5.9	72	213	394
Sept.28		5.9	98	134	280
Sept.30		6.3	112	183	406
Oct. 1		6.2	106	170	310
Oct. 22		6.0	189	48	242
Oct. 29		5.9	50	114	236
Nov. 5		5.9	58	47	234
Nov. 12		5.9	188	766	986
Dec. 9		6.1	92	167	340
Dec. 16		6.2	95	249	400
Jan. 27	1970	5.74	89	227.0	344.0
Feb. 3		6.20	83	58.0	238.0
Feb. 10		6.40	214	1221.0	1350.0
Feb. 17		6.20		260.0	392.0
Feb. 24		6.20	132	277.0	482.0
Mar. 3		5.94	110	96.0	211.0
Mar. 10		6.38	68	58.0	207.0
Mar. 17		6.24	82	82.0	260.0
Mar. 24		6.23	43	14.0	118.0

Table XXV. No. 3 machine sewer, Price Newfoundland, 1969-1970

Date	Year	pH	B.O.D. ppm.	Suspended Solids ppm.	Total Solids ppm.
May 13	1969	6.2	146		
May 20		6.5	252		
May 27		6.0	245		
Sept.19		6.0	328	862	1356
Sept.28		6.1	201	512	798
Sept.30		6.4	217	632	1054
Oct. 1		6.4	196	511	664
Oct. 22		6.5	224	451	696
Oct. 29		6.5	174	1174	1440
Nov. 12		6.2	222	512	852
Dec. 9		6.0	243	950	1102
Dec. 16		6.3	357	670	1112
Jan. 27	1970	6.05	229	414.0	734.0
Feb. 3		6.22	196	329.0	608.0
Feb. 10		6.24	286	885.0	1256.0
Feb. 17		6.15		782.0	968.0
Feb. 24		6.35	273	318.0	720.0
Mar. 3		6.11	227	288.0	592.0
Mar. 10		6.30	293	558.0	914.0
Mar. 17		6.33	242	272.0	642.0
Mar. 24		6.02	206	188.0	470.0

Table XXVI. Woodroom sewer, Price Newfoundland, 1969-1970.

Date	Year	pH	B.O.D. ppm.	Suspended Solids ppm.	Total Solids ppm.
May 20	1969	6.0	138		
May 27		6.2	152		
Sept. 19		6.3	186	479	608
Sept. 30		5.8	155	481	656
Oct. 1		5.2	147	459	898
Oct. 22		5.9	136	400	478
Oct. 29		5.6	92	678	810
Nov. 5		5.6	93	424	612
Nov. 12		5.5	114	710	874
Dec. 9		5.6	114	874	979
Dec. 16		5.7	166	284	508
Jan. 27	1970	5.22	240	660.0	800.0
Feb. 3		5.60	158	252.0	464.0
Feb. 10		5.10	216	521.0	600.0
Feb. 17		6.10		58.0	330.0
Feb. 24		5.35	157	118.0	434.0
Mar. 3		5.40	152	455.0	540.0
Mar. 10		5.81	67	125.0	289.0

to maintain fish life (i.e. a dissolved oxygen content greater than 5 ppm.). In 1969, the lowest recorded dissolved oxygen value was 5.05 ppm. The large dilution capacity and the turbulent flow in the Exploits River are the main reasons that adequate dissolved oxygen concentrations in the river have been maintained despite such a large B.O.D. loading. From June to November of 1969, the Exploits River flows ranged from 2420 c.f.s. to 8730 c.f.s. with the average flow being approximately 5220 c.f.s. When the Exploits River flow is 5000 c.f.s., a 40-fold dilution of mill wastes to unpolluted river water is provided. The turbulent flow common in the Exploits River below Grand Falls assists the river in its re-aeration process and therefore also contributes to maintaining dissolved oxygen concentrations greater than 5 ppm. The large dilution and the turbulent flow provided by the Exploits River have, in the past, prevented a critical dissolved oxygen situation from arising.

The diversion of the headwaters of the Exploits River for the Bay D'Espoir power development is presently underway. This diversion, when completed, will bring about a 20% reduction in the Exploits River flow and therefore, a 20% reduction in its dilution capacity. This reduction in flow, coupled with a further flow reduction resulting from a dry summer, will undoubtedly lead to critical dissolved oxygen concentrations in the river.

Surveys of Exploits River and the Bay of Exploits have indicated that the bulk of the 69.7 tons/day suspended solids discharged by the mill are deposited in the Bay of Exploits rather than the Exploits River. Sediment sampling has indicated that a mat of bark and fiber covers a large area of the Bay of Exploits in the vicinity of the confluence of the Exploits River and the Bay of Exploits. The bark and fiber deposited have undoubtedly destroyed a great deal of the bottom fauna in this part of the bay. During warm summer months, mats of bark and fiber have come to the surface of the bay, causing problems for fishermen working in the area. In the past, the dissolved oxygen concentration has not been a problem in the Bay of Exploits.

Salient Points

(1) Sulfite waste liquor (S.W.L.) produced in the sulfite mill digestion process, has two detrimental effects on the receiving waters. First, S.W.L. has a large oxygen demand and secondly, it is directly toxic to fish at concentrations greater than 500 ppm. In the past, the large dilution capacity of the Exploits River has made adequate dissolved oxygen concentrations and S.W.L. concentrations below 500 ppm. in the river possible.

(2) The combined B.O.D. loading of the municipal wastes from the towns of Grand Falls, Windsor and Bishop's Falls is approximately 1/30 of the B.O.D. loading of the Price mill.

(3) The sampling program revealed that the average suspended solids concentration in the woodroom sewer is 604 ppm. This indicates that despite the bark recovery system, approximately 17.7 tons/day of bark are being discharged to the Exploits River. It should be noted that the 17.7 tons/day figure is definitely a minimum, as a large amount of the bark being discharged is too large to fit into a sample bottle and can therefore not be measured. The bulk of the remaining 69.7 tons/day of suspended solids discharged is fiber.

(4) The measured suspended solids discharge, 69.7 tons/day,is approximately 7.7% of production.

(5) Should waste treatment facilities of any kind be required at the Price mill, the construction of such facilities would be limited by the small area of land available in the vicinity of the mill.

(6) The dam on Red Indian Lake and Millertown is being used to control the flow in the Exploits River. Spring runoff waters are partially contained and discharged during summer months to maintain river flows of at least 5000 c.f.s. during this critical period. It appears that when the Exploits River flow is 5000 c.f.s. or more, the dilution provided by the river prevents a serious dissolved oxygen problem from occurring. The diversion of the headwaters of the Exploits River will mean this Department can no longer depend on the 5000 c.f.s. flow necessary for dilution.

(7) Department plans are presently underway for developing the Exploits River into Newfoundland's most important Atlantic salmon river.

Conclusions and Recommendations

Through the sampling program, it was determined that Price are discharging 86.3 tons/day B.O.D., 69.7 tons/day suspended solids and 526.6 tons/day total solids. It can be expected that these waste loadings will be maintained for some time to come,as no definite process changes are planned. Surveys of the Exploits River have indicated that dissolved oxygen concentrations in the river even during warm summer months, have, in the past, been adequate to maintain fish life. The diversion of the headwaters of the Exploits River for the Bay D'Espoir power development is presently underway. As a result of this diversion, a 20% reduction in the Exploits River flow is expected following completion of the project. With this 20% reduction in the dilution capacity of the river, critical dissolved oxygen concentrations will occur in the river during hot summer months. The bulk of the suspended solids discharged by the mill are being deposited in the Bay of Exploits. The bark and fiber deposited in the bay have undoubtedly destroyed bottom fauna in the area of the bay near the point where the Exploits River and Bay of Exploits meet. Surveys have indicated that dissolved oxygen is not a serious problem in the Bay of Exploits.

It is recommended that the surveys of the Exploits River and Bay of Exploits be continued. In order to be aware of future mill process changes that may affect the pollution situation at the mill, this Department must keep in close contact with mill personnel. Effluent sampling and analysis should be continued periodically in order to measure any changes in effluent quality. Finally, and most important, this Department must continue negotiations with Price Newfoundland Limited with the ultimate goal being a significant reduction in the B.O.D. and suspended solids discharge by the mill. Without solving the Price mill pollution problem, the development of the Exploits River into one of Newfoundland's most important Atlantic salmon rivers would not be feasible.

NEWFOUNDLAND PULP AND CHEMICAL COMPANY LIMITED

Introduction

Newfoundland Pulp and Chemical Company Limited propose to construct and operate an industrial complex at Come-by-Chance, Newfoundland, at the north end of Placentia Bay. This industrial complex is to consist initially of a 600 ton/day newsprint mill; 100,000 barrels/day oil refinery; and a 1000 tons/day anhydrous ammonia plant. An expansion of the pulp and paper mill from 600 tons/day to 900 tons/day is expected by 1975. Initially, the 600 tons of newsprint per day will be produced from 450 tons/day of groundwood pulp and 150 tons/day of sulfite pulp. The sodium base sulfite process is to be employed at this mill and a 60% yield of sulfite pulp is expected, based on the dry weight of wood used in sulfite pulping.

Water Supply and Water Use

Fresh water is to be supplied to the industrial complex from the Come-by-Chance river watershed. It has been estimated that initially, the mill will require 12,000,000 U.S.g.p.d. Following expansion, 15,000,000 U.S.g.p.d. will be required. Five million U.S.g.p.d. will be required for the remainder of the industrial complex. Table illustrates the estimated initial water requirement for the various departments within the mill.

Table . Water requirements within the mill, Newfoundland Pulp and Chemical Company Limited.

Department	Water Requirement U.S.g.p.m.
Wood preparation	500
Mechanical pulp and newsprint manufacture	5700
Sulfite pulp	1800
Steam plant	100

Mill Wastes

The volume of wastes discharged from each department in the mill is essentially the same as the water requirement for that department. Newfoundland Pulp and Chemical Company Limited, in correspondence to this Department, provided predictions of waste discharge characteristics for each mill operation. These predictions will now be presented:

Composition of Process Effluent

1. Wood Preparation

a. Suspended Solids

It is proposed to pass the wood preparation department effluent over screens or drainers. An effluent containing 5000 ppm. of bark and wood fines is anticipated.

b. Dissolved Solids

The pickup of dissolved solids by water used in the wood preparation plant will be minimal.

c. B.O.D.

The B.O.D. of this effluent is caused by the bark and wood fines in suspension. Each pound of such matter is considered to have a B.O.D. of approximately 1.5 lbs.

2. Mechanical Pulp and Newsprint Manufacture

a. Suspended Solids

A fibre loss of 1% of the amount of pulp produced is conservative for these operations in a modern mill, and constitutes the greater part of the suspended solids in the effluent.

b. Dissolved Solids

Negligible quantities of additives are used in groundwood and newsprint manufacture. Consequently, the only idssolved material in the effluent is small amounts of soluble wood components.

c. B.O.D.

Again, the B.O.D. is caused by fine organic matter in suspension, in this case pulp fibre, and amounts to approximately 1.5 lbs. of B.O.D. per pound of such fibre in the effluent.

3. Sulfite Pulp Manufacture

a. Suspended Solids

Softwood sulfite pulp being long-fibered is much less readily lost through the wire mesh of washers and thickeners than groundwood pulp. A loss of ¼ of 1% of the sulfite pulp production is anticipated.

b. Dissolved Solids

The pulp is expected to be produced in approximately 60% yield from the wood, on the dry basis. The amount of woody material dissolved, plus cooking chemicals utilized, is estimated to be 2000 lbs. per ton of pulp produced. This will all appear in the effluent.

c. B.O.D.

A B.O.D. of 500 lbs. per ton of sulfite pulp in the sulfite plant effluent is expected, based on the experience of other mills utilizing this pulping process.

4. Steam Plant

a. Suspended Solids

It is estimated that suspended solids in the steam plant effluent will consist of 150 lbs. per day from boiler blowdown and 3800 lbs. per

Table XXVIII. Estimated waste loadings for process effluents, Newfoundland Pulp and Chemical Co.Ltd.

Department	Flow USgpm	pH	Temp. °F.	Suspended Solids ppm.	Suspended Solids lbs/day	Dissolved Solids ppm.	Dissolved Solids lbs/day	B.O.D. ppm.	B.O.D. lbs/day
Wood preparation	500	6	100	5000	30,000			7500	45,000
Mechanical pulp and newsprint manufacture	5700	6	100	190	13,000			280	19,500
Bisulphite pulp manufacture	1800	6	80	37	800	14,900	324,000	3,700	81,000
Steam plant	100	9	60	3260	3,950	250	300	-	-
TOTALS	8100				47,750		324,300		145,500
Overall ppm				490		3,300		1,480	

day from the boiler fly-ash collectors.

b. Dissolved Solids

The water for the mill is expected to be pure enough, and the boiler pressure low enough that internal water treatment will be sufficient. Consequently, there will be no water treatment either in clarifiers or softening plants with resultant sludge or backwash effluents. The only dissolved material expected to be sewered from the boiler plant will be in the blowdown. Three hundred pounds of dissolved solids per day is estimated.

c. B.O.D.

The boiler plant effluent is expected to have no B.O.D.

Table 28 contains a tabulation of the process effluent properties based on the foregoing. The constituents of the effluent are shown in parts per million and pounds per day. In addition, estimated pH values and temperatures are given. The overall mill effluent is estimated to amount to 8100 U.S.g.p.m. and to contain 490 ppm. suspended solids, 3300 ppm. dissolved solids and 1480 ppm. B.O.D. It is planned that sanitary wastes will be handled in a separate system or systems. No significant amount of dissolved solids, suspended solids, or B.O.D. is expected in the effluent from this system.

Comments

The key pollution parameters to be considered are suspended solids and B.O.D. The Company predicts that with no waste treatment, an overall discharge of approximately 73 tons of B.O.D. and 24 tons of suspended solids per day from the pulp and paper mill will result. Based on experience with the operations and waste discharges at Price Newfoundland Limited and

Bowaters Newfoundland Limited and a literature review, it is the writer's opinion that the B.O.D. and suspended solids predictions are definitely "reasonable" but each could quite easily be as much as 15% higher than the actual B.O.D. and suspended solids discharge that will occur during production.

Initial Proposal for Disposal of Process Effluent

Originally, Newfoundland Pulp and Chemical Company Limited proposed to dispose of their wastes by passing them untreated through a diffuser pipe to Placentia Bay. With an adequate initial dilution, they believed that there would be no objectionable solids, accumulation, water discoloration or oxygen deficiency. They estimated that a 493-fold initial dilution of wastes with sea water was required and that this initial dilution coupled with a further dilution of the wastes due to tidal movements and currents in Placentia Bay, adequate protection of Placentia Bay waters and marine life would be provided. The 493-fold initial dilution was to be provided by a properly designed underwater diffuser system.

Since 1967, the time at which this proposal was submitted, government requirements for pollution control have increased considerably. The discharge of untreated wastes to salt water, once readily accepted, was no longer a satisfactory means of waste disposal. Recently, this Department informed Newfoundland Pulp and Chemical Company Limited that their preliminary proposal for waste disposal would not be adequate and that waste treatment to meet specified effluent standards would be required. The amount and type of waste treatment required and the effluent standards to be met have not as yet been determined.

Preliminary Pulp Mill Effluent Standards

Prior to presenting the pulp mill effluent standards prepared by the writer, for Newfoundland Pulp and Chemical Company Limited, two points should be made clear. First, the standards determined are preliminary and require additional work and secondly, the standards provide an upper limit for the amount of suspended solids and B.O.D. that this Department should permit the Company to discharge.

Suspended Solids Discharge: Standard - Loss not to exceed 1% of production (i.e. 6 tons/day)

The suspended solids (bark, fibre and wood) loss for the mill must not exceed 1% of production (approximately 6 tons per day). Modern pulp mills with no external waste treatment show suspended solids losses of about 2% of production. With an extremely tidy operation, this 2% suspended solids loss can be even somewhat lower. Additional treatment facilities (e.g. settling ponds or tanks) can bring about a further reduction in suspended solids to meet the required 1% suspended solids loss. Also, the presence of a settling pond or tank will provide additional insurance against unusually high losses during periods of spills and other plant malfunctions. Waste streams from the groundwood mill, paper mill, and wood preparation operations all contain a considerable amount of suspended solids and should therefore be given primary treatment. Primary treatment would also remove the inert suspended solids (2 tons/day) from the steam plant effluent. The sulfite mill digester discharge containing the S.W.L. need not be given primary treatment because of its low suspended solids concentration.

B.O.D. Discharge: Standard - 15 tons/day discharged

For the sulfite mill, the untreated effluent contains 400-600 lbs. of B.O.D. per ton of sulfite pulp. The Newfoundland Pulp and Chemical Company plant is designed to produce 150 tons/day sulfite pulp. The resulting B.O.D. loading in the effluent can be expected to be between 30 and 45 tons/day. Newfoundland Pulp and Chemical Company predict the B.O.D. discharge to be approximately 40 tons/day for the sulfite mill operation alone. Wood processing, groundwood pulping, and papermaking may be expected to produce an additional B.O.D. loading of between 10 and 15 tons/day. The total B.O.D. loading of the pulp mill may be expected to be between 40-60 tons/day. Properly designed and operated biological or secondary treatment units (e.g. oxidation ponds) if employed will reduce the B.O.D. loading to the required 15 tons/day.

Sulfite Waste Liquor: Standard - Less than 500 ppm. in effluent

The sulfite waste liquor concentration in the effluent may not exceed 500 ppm. This figure can usually be easily attained by dilution of sulfite mill wastes with other mill waste streams. Secondary treatment, if provided, will further reduce the S.W.L. concentration.

Conclusions and Recommendations

At this point, it is impossible to draw any definite conclusions as to the effect of the mill effluent on the marine life of Placentia Bay, as a great deal of essential information is still lacking (e.g. the plans for the design of the new mill, the results of tidal movements and current studies in Placentia Bay, etc.). It is recommended, therefore, that negotiations between this Department and the Company are resumed in the near future. Hopefully, as a result of these negotiations, an adequate waste disposal system, one which will reduce pollution to the point where it will be harmless to marine life, can be agreed upon. A survey to determine the water quality and biology of Placentia Bay in the Come-by-Chance area conducted prior to the mill going into production will provide valuable background data for future reference.

JAVELIN PULP AND PAPER COMPANY LIMITED

Introduction

Javelin Pulp and Paper Company Limited propose to construct and operate a pulp and paper mill at Stephenville, Newfoundland, on the north shore of St. George's Bay. The Kraft pulping process will be employed at the mill in order to produce linerboard at the rate of 1000 tons per day initially. A future expansion of the mill is expected. The unbleached Kraft process will be employed although bleaching may be added as part of the expansion program.

Water Supply and Water Use

It has been proposed that water for the mill be obtained from Harry's River. Initially, 25,000,000 U.S.g.p.d. will be required by the mill (i.e. 25,000 U.S. gallons per ton of product). A breakdown of water requirements for the various operations within the mill is not available at this time.

Mill Wastes

The volume of wastes discharged from the mill is essentially the same as the water requirement for the mill. Javelin Pulp and Paper Company Limited, in correspondence to this Department, provided predictions of waste loadings for various pollutants in their effluent. These predictions will now be presented.

(1) B.O.D. in Effluent

It is expected that the B.O.D. in the effluent will amount to 30 to 40 lbs. per ton of pulp (i.e. 30,000 to 40,000 lbs. of B.O.D. discharged daily).

(2) Dissolved Solids

The total dissolved solids discharged is expected to equal 180 lbs./ton of product (i.e. 180,000 lbs. of dissolved solids discharged daily).

(3) Suspended Solids

The total suspended solids discharged is expected to be approximately 20 lbs./ton of product (i.e. 20,000 lbs. of suspended solids discharged daily).

(4) Toxicity

The more toxic components of kraft mill wastes are:

(a) sulfate soaps

(b) mercaptans

(c) sulfides

The mercaptans and sulfides are quite unstable and seldom occur in dangerous concentrations beyond the sewer outfall. The soaps are relatively stable and may be the major contributors to the toxicity of kraft pulp mill wastes.

The values, obtained from Melville Pulp and Paper Company Limited and presented in this section of the report, are within the range of values reported in the literature for waste discharge from an unbleached Kraft mill.

Initial Proposal for Process Effluent Disposal

A general description of the effluent system proposed in 1967 by Javelin Pulp and Paper Company Limited is as follows:

(a) Sanitary wastes are to be treated in a package sewage treatment plant or septic tank system.

(b) Mill sewers are to be divided into three sections:

(1) Fresh Water lines, collecting only uncontaminated water such as roof drains, yard storm sewers, etc. These will be discharged directly to the harbour.

(2) Neutral fibre sewer line, collecting wastes which contain pulp solids but little dissolved chemical contamination. This will be taken to the measuring and sampling control house, where the effluent will be continually monitored for quality and quantity.

(3) Alkaline sewer line, collecting all other wastes which may have chemical contamination. This will be taken to the measuring and sampling control house, where the effluent will be continually monitored for quality and quantity.

(c) After the control house, the neutral and alkaline wastes are to be mixed in a single line and discharged to sea by an underwater diffuser pipe. A study of the coastal tides and currents will be necessary to determine the proper length of pipe and location to achieve satisfactory dispersion.

(d) The system will be laid out so that clarification for solids removal and secondary treatment for B.O.D. removal can be added in the future.

Conclusions and Recommendations

Before any conclusions can be brought forward concerning the possible effects of the mill wastes on the marine life of St. George's Bay, more information must be obtained concerning mill processes and tidal and current movements in St. George's Bay. The above proposals for waste disposal were made by Javelin in 1967. The company at that time assumed that dilution was an adequate solution to their future pollution problem. In 1970, dilution cannot be considered as an acceptable solution to this pollution problem. Therefore, it is recommended that this Department resume negotiations with Javelin Pulp and Paper Company Limited leading to the construction of an adequate waste disposal system for the mill. Effluent standards must also be established. A survey to determine the water quality and biology of St. George's Bay in the Stephenville area conducted prior to the mill going into production will provide valuable background data for future reference.