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Development Document for
Effluent Limitations Guidelines
and Standards of Performance

BUILDERS, PAPER AND BOARD INDUSTRY

Prepared by WAPORA, Inc.
for the

United States
Environmental Protection Agency
Under Contract Number 68-01-1514

Dated: June 1973

NOTICE

The attached document is a DRAFT CONTRACTOR'S REPORT. It includes technical information and recommendations submitted by the Contractor to the United States Environmental Protection Agency ("EPA") regarding the subject industry. It is being distributed for review and comment only. The report is not an official EPA publication and it has not been reviewed by the Agency.

The report, including the recommendations, will be undergoing extensive review by EPA, Federal and State agencies, public interest organizations and other interested groups and persons during the coming weeks. The report, and in particular the contractor's recommended effluent limitations guidelines and standards of performance, is subject to change in any and all respects.

The regulations to be published by EPA under Sections 304(b) and 306 of the Federal Water Pollution Control Act, as amended, will be based to a large extent on the report and the comments received on it. However, pursuant to Sections 304(b) and 306 of the Act, EPA will also consider additonal pertinent technical and economic information which is developed in the course of review of this report by the public and within EPA. EPA is currently performing an economic impact analysis regarding the subject industry, which will be taken into account as part of the review of the report. Upon completion of the review process, and prior to final promulgation of regulations, an EPA report will be issued setting forth EPA's conclusions concerning the subject industry, effluent limitations guidelines and standards of performance applicable to such industry. Judgments necessary to promulgation of regulations under Sections 304(b) and 306 of the Act, of course, remain the responsibility of EPA. Subject to these limitations, EPA is making this draft contractor's report available in order to encourage the widest possible participation of interested persons in the decision making process at the earliest possible time.

The report shall have standing in any EPA proceeding or court proceeding only to the extent that it represents the views of the Contractor who studied the subject industry and prepared the information and recommendations. It cannot be cited, referenced, or represented in any respect in any such proceedings as a statement of EPA's views regarding the subject industry.

U.S. Environmental Protection Agency
Office of Air and Water Programs
Effluent Guidelines Division
Washington, D.C. 20460

DEVELOPMENT DOCUMENT FOR EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE FOR THE BUILDERS PAPER AND BOARD INDUSTRY

Prepared For
The
United States Environmental Protection Agency

June 1973

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ABSTRACT

This document presents the findings of an extensive study of the building paper and roofing felt segment of the builders paper and board industry by WAPORA, Inc. for the purpose of recommending to the United States Environmental Protection Agency effluent limitations guidelines and standards of performance in compliance with Sections 304(b) and 306 of the Federal Water Pollution Control Act Amendments of 1972 (the "Act").

The building paper and roofing felt segment of the industry is defined as one discrete subcategory in this study.

Effluent limitations guidelines are set forth for the degree of effluent reduction attainable through the application of the "Best Practicable Control Technology Currently Available," and the "Best Available Technology Economically Achievable," which must be achieved by existing point sources by July 1, 1977 and July 1, 1983, respectively. The "New Source Standards of Performance" set forth the degree of effluent reduction which is achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives. The proposed guidelines recommend biological waste treatment as the base technology for 1977, and major internal mill improvement and biological waste treatment as the base control and treatment technologies for both existing and new mills in 1983.

Supportive data and rationale for development of the proposed effluent limitations guidelines and new source performance standards are contained in this report.

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FIGURES

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SECTION I

CONCLUSIONS

Notice

> This document is a preliminary draft. The conclusions which have been reached reflect the technical judgment of WAPORA, Inc. based on information developed in conjunction with our subcontractors, and with the assistance of the Environmental Protection Agency and the cooperation of the National Council of the Pulp and Paper Industry on Air and Stream Improvement. It is being circulated for comment on its technical accuracy and policy implications.

The subject of this report is the builders paper segment of the builders paper and board industry. The other segment of this industry, builders board, including hard board, is covered in a separate report on the timber products industry. For the purpose of establishing effluent limitations guidelines and standards of performance, the builders paper segment, commonly referred to as the building paper and roofing felt segment, is a single discrete subcategory.

Within the building paper and roofing felt subcategory, factors such as age, size of plant, process employed, climate, and waste treatability confirm and substantiate this subcategorization for the purpose of establishing effluent limitations and performance standards to be achieved through the application of recommended treatment and control technologies.

At this time, some mills within the subcategory are achieving the 1977 requirement of best practicable technology currently available. It is estimated that increases in production costs to achieve this level will average $8.60 per metric ton ($7.80 per short ton) but will vary depending upon specific mill conditions relating to available technologies at that location. This technology level suggests biological waste treatment as the basic treatment process and limitations on BOD_5, suspended solids, and pH range are set forth.

Best available technology economically achievable is a requirement for 1983, and a few mills in the subcategory studied are currently achieving this for most identified pollutants. The estimated increases in production costs of upgrading existing mills from the 1977 requirements to those of 1983 will average from less than $11.58 per metric ton ($10.50 per short ton), but will vary depending on specific mill conditions. This technology level suggests major internal mill improvements,

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biological waste treatment, and some physical-chemical waste treatment as the basic treatment and control processes, and limitations on BOD_5, suspended solids, and pH range are set forth.

New source performance standards are proposed which reflect internal improvements which can be achieved through effective design and layout of mill operations. Effluent limitations are set forth on BOD_5, suspended solids, and pH range at levels above those cited for existing mills by 1977. The basic treatment and control processes which are suggested as a means of meeting these effluent standards are similar to those proposed for existing mills by 1983.

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SECTION II

RECOMMENDATIONS

Based upon the information in the body of this report, the following effluent limitations guidelines and standards of performance are recommended for the building paper and roofing felt subcategory.

Recommended Effluent Limitations Guidelines
and New Source Standards of Performance
Pounds Per Short Ton of Production

Level	BOD_5	Suspended Solids	pH Range
Best Practicable Technology Currently Available	5.0	3.0	7.5-8.5
Best Available Technology Economically Achievable	2.5	1.5	7.5-8.5
New Source Standards of Performance	4.0	2.5	7.5-8.5

The allowable pounds of pollutants per ton of production are to be based upon monthly averages of daily values as determined from industrial records. It is expected that values on any given day could exceed these guidelines. Further, values may be adjusted to reflect variations in performance as a result of changes in materials mix, ambient air temperature effect on waste treatment process performed, and other local conditions.

Production capacity is defined as the total production off the machine, including reprocessed broke. Daily production, in air dry tons, is defined as the highest average level sustained for seven consecutive operating days of normal production.

Values are intended to reflect the net pounds per ton of product which are attributed to the industrial operation, and do not account for "background" pollutional loads which may have existed in the process water prior to use by the industry.

These recommended levels can be achieved through the application of available treatment and control technologies, and no extensive research into new methods is required.

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SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

Section 301(b) of the Federal Water Pollution Control Act, as amended in 1972, requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best available technology economically achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) of the Act. Section 306 of the Act requires the achievement by new sources of a federal standard of performance providing for the control of the discharge pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.

Section 304(b) of the Act requires the Administrator to publish within one year of enactment of the Act, regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operation methods, and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for the builders paper segment of the builders paper and builders board point source category.

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b)(1)(A) of the Act, to propose regulations establishing federal standards of performance for new sources within such categories. The Administrator published in the Federal Register of January 16, 1973, (38 F.R. 1624), a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources within the builders paper and builders board point source category, which was included within the list published January 16, 1973.

This report proposes such standards for the building paper and felts segment of this point source category.

SUMMARY OF METHODS USED FOR DEVELOPMENT OF THE EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE

The effluent limitations guidelines and standards of performance proposed herein were developed in the following manner. The point source category was first subcategorized for the purpose of determining whether separate limitations and standards are appropriate for different segments within a point source category. Possible subcategorization was evaluated upon raw material used, product produced, manufacturing process employed, and other factors. The raw waste characteristics for each possible subcategory were then identified. This included an analysis of 1) the source and volume of water used in the process employed and the sources of waste waters in the plant and 2) the constituents (including thermal) of all waste waters including toxic constituents and other constituents which result in taste, odor, and color in water or aquatic organisms. The constituents of waste waters which should be subject to effluent limitations guidelines and standards of performance were identified.

The full range of control and treatment technologies existing within each possible subcategory was identified. This included an identification of each distinct control and treatment technology, including both inplant and end-of-process technologies, which are existent or capable of being designed for each subcategory. It also included an identification in terms of the amount of constituents (including thermal) and the chemical, physical, and biological characteristics of pollutants, of the effluent level resulting from the application of each of the treatment and control technologies. The problems, limitations, and reliability of each treatment and control technology and the required implementation time were also identified. In addition, the non-water quality environmental impact, such as the effects of the application of such technologies upon other pollution problems, including air, solid waste, noise, and radiation were also identified. The energy requirements of each of the control and treatment technologies were identified as well as the cost of the application of such technologies.

The information, as outlined above, was then evaluated in order to determine what levels of technology constitute the "best practicable control technology currently available;" "best available technology economically achievable;" and the "best available demonstrated control technology processes, operating methods, or other alternatives." In identifying such technologies, various factors were considered. These included the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques or process changes, non-water quality environmental impact (including energy requirements), and other factors.

The extensive data base for identification and analyses was derived from a number of sources. These sources included EPA research and demonstration project information, including previous EPA industrial waste and state-of-the-art treatment studies of the pulp and paper industry; published literature; Refuse Act Permit Program (RAPP) applications; and National Council of the Pulp and Paper Industry for Air and Stream Improvement(NCASI). This data base was verified by on-site surveys of two mills which included sampling and analysis of waste streams. References used in developing the guidelines for effluent limitations and standards of performance for new sources reported herein are included in Section XIII of this document.

GENERAL DESCRIPTION OF INDUSTRY SEGMENT

This report pertains to the builders paper segment of the builders paper and board point source category. The terms building papers and roofing felts are more commonly applied to the products of this segment and are, of course, aptly descriptive of heavy papers used in the construction industry. As a group, they are identified more by nomenclature appropriate to their use rather than by significant variations in the raw materials or the process used to manufacture them. Both products are composed of varying combinations of wood, waste paper and/or rags, and/or asbestos fibers. The process used for the production of both types of product is similar in concept, differing basically to accommodate the particular combinations of raw materials used. Each of the raw materials described above requires different equipment to reduce the material to individual fibers. The fibers are then blended in varying proportions and formed on a paper machine which is common to both types of product.

Building papers are generally characterized as saturating papers, flooring paper, and deadening papers which are used in the construction and automotive industries. They differ from unstructured roofing felts only in thickness and possible chemical additives added to the process in order to achieve a specific property, i.e., strength, density, wet strength, water repellant capability, or similar physical qualities.

The function of dry roofing felt is to provide a strong, highly absorbent material as support and backing for the bituminous coatings necessary for the water-proofing characteristics essential to the finished product (1). One or more saturating coats of melted asphalt are applied to the finished roll of felt in a process which follows the papermaking process. If the product is a roofing roll, the sheet is given a thin coat of mica and talc after the saturating process and is then the finished product. "Mineral-surfaced" products used as roof-flashing rolls or shingles, are surfaced with granules of slate, stone, or ceramic following the saturating and talc processes (2). This coating provides resistance to weathering and to damage caused by roof maintenanance activities. Roll roofing does not require this granular coating since it is protected by gravel placed in a heavy coat of bitumen when installed. Roll roofing felts of wood and asbestos fibers are exceptionally strong and weather and heat resistant, making it possible to install them without providing a protective coat of gravel or granular material. The roofing materials described above account for a high percentage of the production of the mills which are the subject of this report.

The objective of this project is to study mills that generate a wasteload that is attendant to the manufacture of building paper and roofing felt. Some of these products are made by mills which also produce other paper and paperboard products manufacturing building paper and dry felt only on an intermittent basis. These products also derive from mills which produce both building paper and building board, insulating board, or other combinations of products. In keeping with the objective, therefore, this report deals exclusively with those mills which produce building papers and felts as their primary product.

Sixty-two mills which exemplify this group are listed in Appendix 1. Although there is some overlapping, they are divided generally in accord with their announced production as follows:

Dry Roofing Felt	7 mills
Saturated/Coated Roofing Felt	40 mills
Asbestos Paper and Gasket	6 mills
Combination of The Above	9 mills

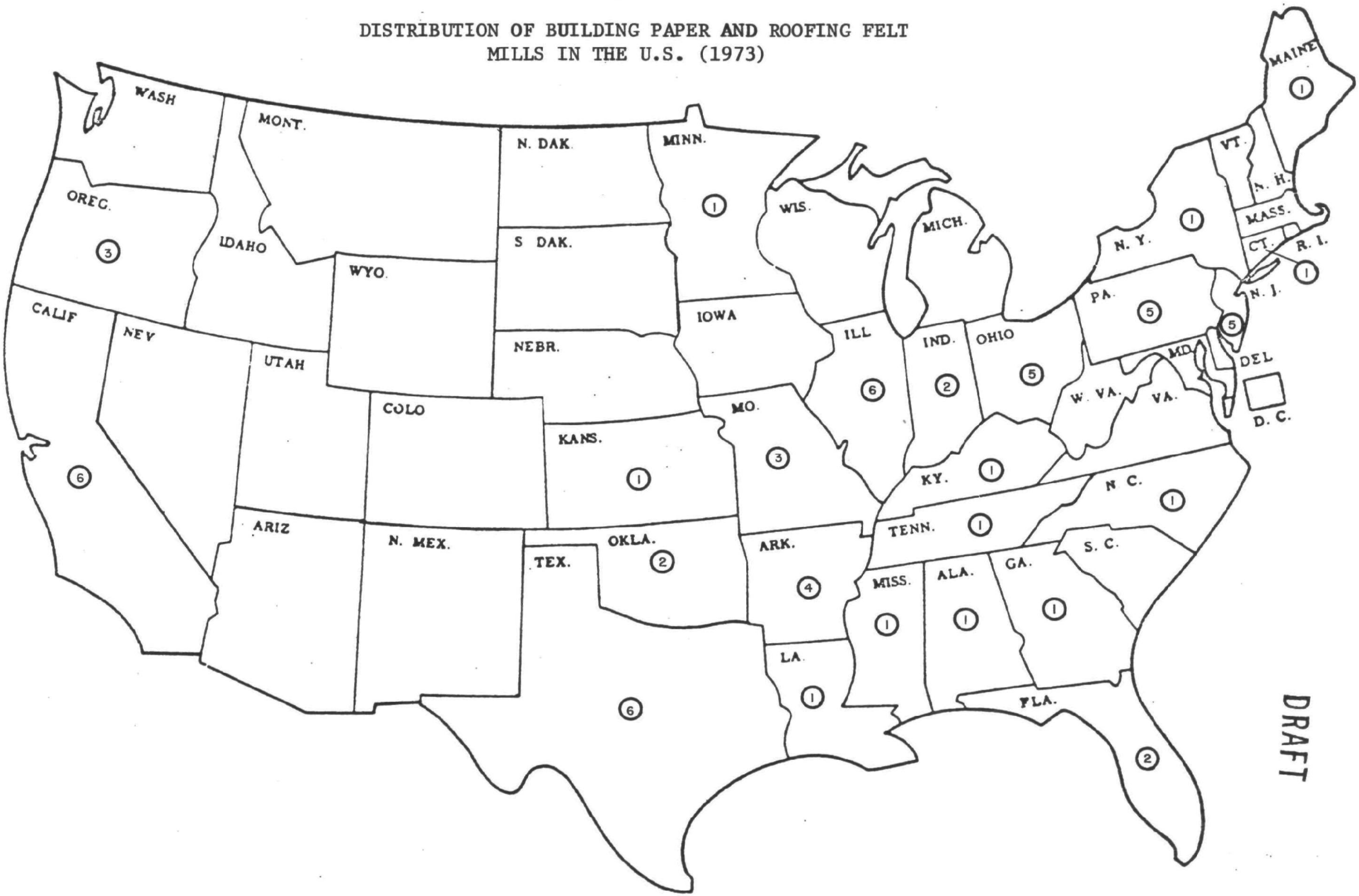
It was found during the course of this study that these mills quite frequently change their production, discontinuing one or more products and introducing new ones. Thus, this list is illustrative only.

The total daily production capacity of these 60 mills is approximately 5447 metric tons (6,000 short tons) per day. The daily capacity of the largest mill is 295 metric tons (325 short tons) and the smallest output is 20 metric tons (22 short tons).

They are geographically distributed over most of the United States as illustrated in Figure 1. The majority of them are located in or near metropolitan areas where the quantity of waste paper required is

Figure 1

DISTRIBUTION OF BUILDING PAPER AND ROOFING FELT
MILLS IN THE U.S. (1973)



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available. Because they are so located, many of them, 60 to 75 percent is estimated, dispose of their wastes in municipal sewerage systems.

Total annual U.S. production of construction paper, the term utilized by the Bureau of the Census and the American Paper Institute (API) in 1971 was 1,473,316 metric tons (1,622,952 short tons) (3).

PRODUCTION PROCESSES

In terms of quality, raw material requirements for building paper and felt are not, generally, as demanding as those for finer grade papers. Thus, more flexibility exists in those that can be used and in the way they are prepared. These products generally consist of waste paper and defibrinated wood, wood flour, or pulp mill rejects although some rags, asbestos, or other materials can be employed.

Some mills receive wood as logs which are chipped on the premises. Others purchase wood chips, sawdust, or wood flour. Or in the case of many mills, equipment is available to handle these materials alternatively.

Rags and waste paper arrive at the mill in bales. Old, low grade rags not suitable for recycling into fine paper may be utilized for building paper and felt. Similarly lower specifications for reclaimed paper result in frequent variations in quality of this raw material.

Various specifications require different preparations of raw materials to impart desired characteristics such as strength, absorptive capacity, heat and flame resistance, and flexibility.

The furnish for roofing felt must be such that the product can meet specifications of weight, tensile strength, and flexibility to enable it to withstand any strain to which it may be later subjected in the roofing plant (2). It must be able to absorb from two to three times its weight in bitiminous saturants and six times its weight in saturants and granule coatings.

Stock Preparation

Fibers are prepared for use by various methods which are determined by the fiber source. Wood chips are pulped mechanically in an attrition mill. This is a refiner containing fixed and rotating discs between which the chips pass on a stream of water. In some operations, this is preceded by cooking, or steaming, the chips with water for a short period in a digester, a large metal pressure vessel. This softens the chips and reduces the mechanical energy required. Chemicals are not generally utilized.

The pulp is discharged from the attrition operation as a slurry which goes to a stock chest for storage. It is then blended with other raw materials. Wood flour requires no pretreatment and enters the system in the blending chest.

After they are cut and shredded, rags are placed, along with fresh and/or process water, in a beater tank at about six percent consistency. Here a rotating cyclindrical bladed element, which operates in conjunction with stationary blades, both impacts the fiber and causes its continuous circulation around the beater and back through the attrition zone. Thus, progressive fiberizing occurs. After a period of several hours, when the charge is sufficiently defibered, the pulp is diluted and removed to a dump chest (3).

Waste paper is similarly treated in beaters or pulpers. In the pulper operation, the paper follows the water circulation in a large open vat and is repeatedly exposed to rotating impeller blades. Over a period of time it is ripped, shredded, and finally defibered (1). Accessory equipment separates and removes metal and other contaminants.

After the stock is blended, it is subjected to refining and screening ahead of the forming process.

Some building papers are highly sized with resins and alum. Felts may be sized with bituminous materials or contain mold-proofing or fungicidal materials.

Papermaking

These products are manufactured principally on single-cylinder paper machines from the raw materials reduced to fiber in the stock preparation area and transported to the machine in a dilute slurry. A rotating wire-covered cylinder retains the fibers which form a sheet on its surface and permits water to drain through. This sheet is then removed from the wire by a cloth felt which carries it through a press section where additional water is removed from the sheet. It is self supporting as it leaves the press sections and passes through the steam-heated multi-drum drier section from which it is cut to width and rolled. At this stage it is considered a dry or unsaturated felt. The above paper forming and drying process is the type used by all manufacturers treated in this study.

A process flow diagram of a building paper and roofing felt mill is shown in Figure 2.

PRODUCTION CLASSIFICATION

The U. S. Bureau of the Census, Census of Manufactures (4), classifies construction paper (dry basis before saturating) as Product Code No. 26612 under the four-digit category 2661, building paper and board.

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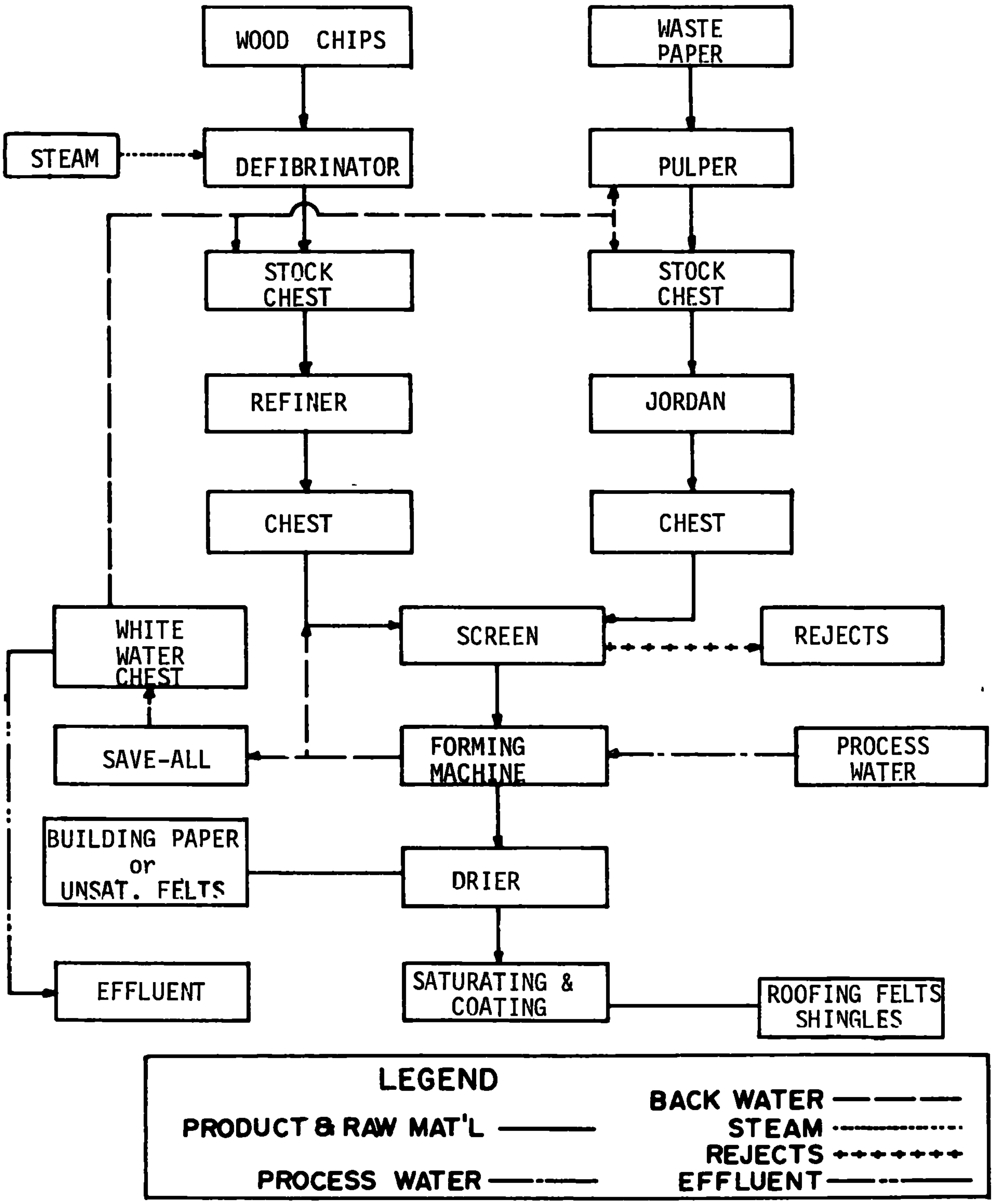
FIGURE

BUILDING PAPER AND ROOFING FELT PROCESS DIAGRAM



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CAPACITY PROJECTIONS

Only a very minor increase in construction paper capacity is forecast through 1975 (5). The percentage of waste paper used as a constituent is projected to rise from 27.1 percent in 1969 to 40 percent in 1985 (6). Research, development, and implementation of programs in response to environmental problems associated with the disposal of solid wastes, to which "paper" makes a large contribution, may support this projection.

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SECTION IV

SUBCATEGORIZATION OF THE INDUSTRY

FACTORS OF CONSIDERATION

This study is concerned with the building paper and roofing felt segment of the builders paper and board mills point source category. In order to identify any relevant discrete subcategories within this segment, the following factors were considered:

1. Raw materials
2. Production processes
3. Products produced
4. Size and age of mills
5. Waste water characteristics and treatability
6. Geographical location

After analyzing these factors, it is concluded that this segment constitutes one discrete subcategory defined as BUILDING PAPER AND ROOFING FELT, which is the production of heavy papers used in the construction industry from cellulose and mineral fibers derived from waste paper, wood flour and sawdust, wood chips, asbestos, and rags, without bleaching or chemical pulping.

RATIONALE FOR SELECTION OF SUBCATEGORY

Raw Materials

Cellulose fiber is the principal raw material used. Asbestos fiber is used to a much lesser degree. While there are differences in the sources of these fibers, as noted above and in Sections III and V, such differences have only a minor impact on waste water characteristics and treatability. All raw waste containing cellulose respond to the same treatment techniques for removal of suspended solids and BOD_5. Raw wastes containing asbestos respond to the same suspended solids removal techniques, and have no BOD_5. The details of these techniques are described in Section VII.

Other raw materials, such as asphalt used in some roofing felt mills, do not contribute significantly to waste water characteristics, as described in Section V.

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Production Processes

As delineated in Section III, there is a wide variety of products produced, ranging from roofing felts to gasket materials. As shown in Section V, waste water characteristics do not vary significantly as a function of product produced.

Size and Age of Mills

While older mills tend to have higher levels of pollutants in the waste water than newer mills, there are "old" mills which have applied available technology, principally in the area of recycle, to reduce such pollutant levels to approach those obtained by "new" mills. Size of most mills varies only within a relatively narrow range from about 50 to about 250 tons per day.

Geographical Location

Waste water characteristics and treatability do not differ significantly with geographical location. Climatic differences, however, have an important effect upon treatability due to the effect of temperature upon some biological treatment methods used to remove BOD_5. This accounts for the inclusion of temperature effects as an influencing factor in the effluent limitation guidelines and standards.

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SECTION V

WATER UTILIZATION AND WASTE CHARACTERISTICS

PROCESS WATER UTILIZATION

General Use

A building paper and/or roofing felt mill utilizes water in its process, exclusive of steam generation, for the following purposes:

1. To act as an agent for separating the raw materials into discrete fibers which is essential for: the formation of the end product; the removal of contaminants and undesirable fibers from the stock system; and the control and metering of stock to the paper machine. This water, which is generally recycled, acts as a vehicle for transporting the fiber to the process.

2. To clean those areas, particularly on the wet end of the machine, which tend to develop fiber buildup. These areas are the paper forming section of the machine and the felts used to carry the formed sheet through the machine and press sections. This water enters the system via shower nozzles and represents the largest contribution to the volume of raw waste water generated since it is nearly all excess water in terms of process water needs.

3. To keep production equipment throughout the mill operational or permit the equipment to perform its design function. Typical applications are the seal and cooling waters used on pumps, agitators, drives, bearings, vacuum pumps, and process controls. Also cooling water is required by those mills that include the asphalt saturating process for the production of roofing felts and shingles. This water represents the second largest contributor to the volume of waste water generated by the process.

4. To supply emergency make-up water, under automatic control, to various storage tanks to avoid operational problems resulting in reduced production and/or complete mill shut down.

5. To provide power boiler condenser, heat exchange condensate, and non-contact cooling water that can be segregated and discharged separately without treatment. However, there are many mills that still permit all or part of this water to enter the waste water sewer system which increases the volume of water requiring treatment.

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Specific Process Use

The manufacture of building paper involves three relatively discrete process systems in terms of quantity and quality of water utilization: stock preparation and the wet end and dry end of the machine. An illustrative process flow diagram is shown in Figure 3.

Stock Preparation Area

The stock preparation area uses water for purposes described in Items 1, 3, 4, and 5 of the General Use section. Water in the form of steam may also be used directly to maintain stock temperature which contributes to the volume of waste water generated since it represents excess water in terms of the process water balance.

Process water is mixed with baled waste paper in the pulper or beater and the resulting slurry is then carried through the stock cleaning system where additional process water is introduced. The stock is then thickened to reduce consistency for refining or jordaning (fiber control). The process water removed by the thickener or decker is recirculated back to the pulper and cleaning system. A mill utilizing wood flour instead of wood pulp from an attrition mill adds the flour in the above waste paper stock system ahead of the jordans or refiners. However, those that use wood chips and/or rags and/or inorganic materials such as asbestos require a preparation process for each type of furnish used. These are generally low volume water users although each system contributes to the waste load generated. The various stock components are blended and passed through the refiners and discharged to a machine stock chest.

Wet End Area

The stock is pumped to a head box which meters the quantity of stock to the paper machine. At this point process water is added to reduce the stock consistency to 0.25-0.5 percent in the vat which is the forming section of the machine. The stock deposits on a cylinder wire and the excess machine white water passes through the wire. A large portion of this white water is recycled back through the machine stock loop and the excess is pumped to a white water collection chest for reuse in the stock preparation area. It is on the wet end that excess water is created by the use of fresh water showers as described in Item 2 of the General Use Section. The sheet is carried by felts to the press sections where additional quantities of water are removed. Felt cleaning showers add more excess water, but are necessary for the maintenance of the drainability of the felt.

Dry End Area

The sheet passes through the drier section to the dry end where water use is generally low in volume consisting principally of cooling water and sheet moisture control. The product at this point may be the finished product or it may be subject to additional processes in the mill. For

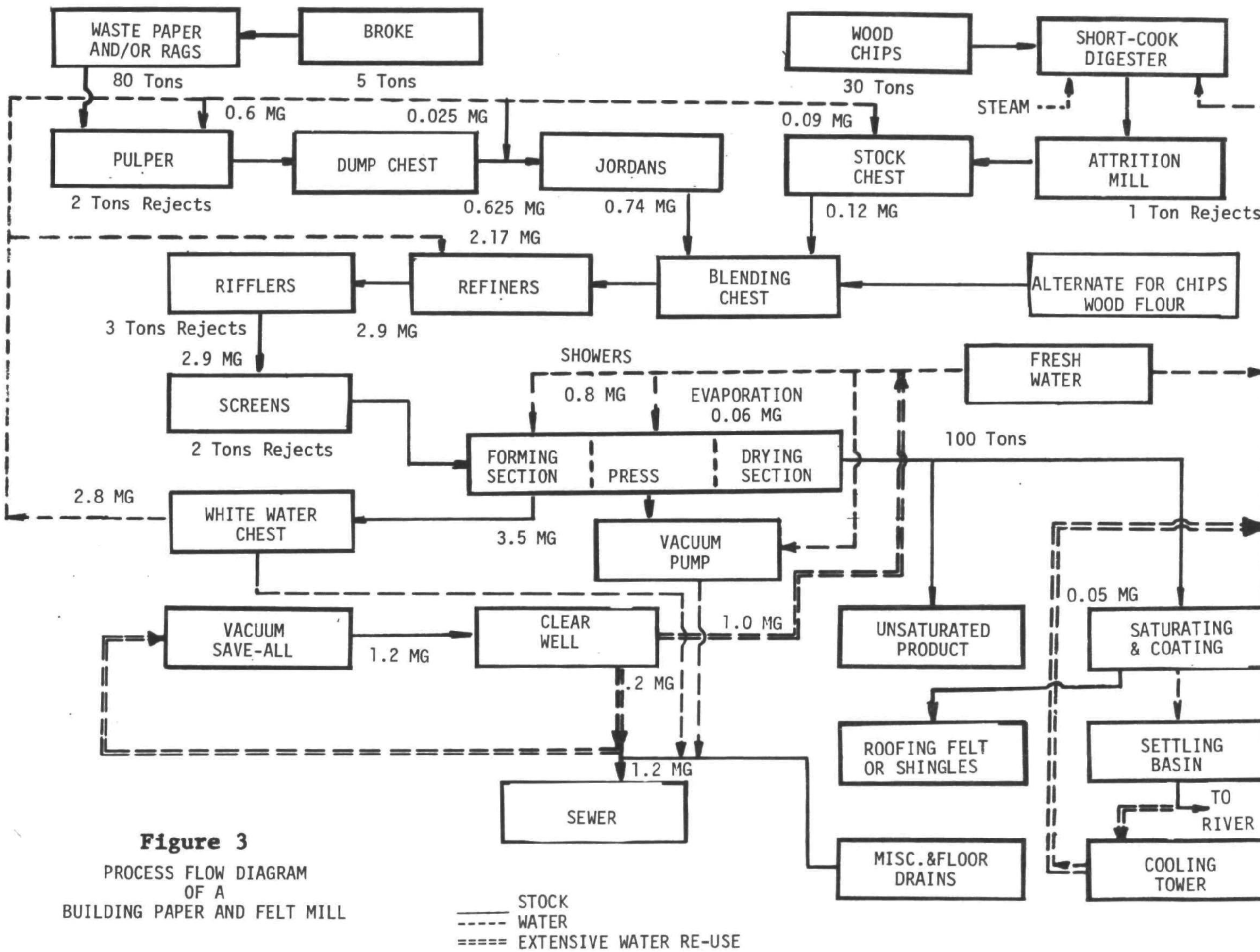

Figure 3

PROCESS FLOW DIAGRAM
OF A
BUILDING PAPER AND FELT MILL

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some products, the saturating process is the next waste generating step after the papermaking process. However, the production of deadening or flooring felts from the paper produced does not require processing which generates a waste water load.

Asphalt Saturating Process

The paper is carried through one or two stations for asphalt saturation and application of a coat of talc on one side of the sheet. This requires the utilization of cooling water applied by spray nozzles after each saturation which represents the waste load sewered from the area. This process has the capability of making roofing shingles as well as roofing felts, therefore a section for coating the saturated felt with a granular stone and/or mica is part of the operation. These particles fall to the floor and are washed to the sewer and represent the principal source of inert suspended solids in the waste water generated in the area. As explained in Section VII, the volume of water used for this application varies widely, and the resulting waste water is very low in BOD_5.

UNIT PROCESS WASTE LOADS

Definitive data on individual waste loads from each of the above process sources do not presently exist, and are difficult to develop: First, many, if not most, mills in this subcategory change raw materials and products manufactured in response to short term pricing, availability, and demand. Figure 3 demonstrates the complexity of processs options which may be used in even a single mill in response to these factors. Second, the pronounced tendency in these mills toward increased recycle could erroneously attribute a waste load to one unit process which actually originated in another. Such recycle. as explained below and in Section VII, reduces pollutant levels in the raw waste and in the final discharge.

TOTAL RAW WASTE LOAD

Definition of "total raw waste load" from mills in this subcategory is subject to interpretation dependent upon the particular scheme of recycle used. Four principal schemes have been identified, each being effective insofar as reduction of final discharge pollutants is concerned, and each dependent upon product quality, mill layout, and other factors:

1. An internal device such as a save-all or DSM screen is used to remove suspended solids. Both the solids and the clarified process water may then be recycled, at least in part, resulting in a low "raw waste" level of suspended solids.

2. An external device such as a mechanical clarifier is used to serve the same functions. The influent to the clarifier may technically be called "raw waste," but any effluent not reused would be the definition comparable to scheme #1.

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3. In both above cases, suspended solids removal may be followed by biological treatment. The third scheme employes recycle of a portion of the effluent after biological treatment, in which case, the remaining effluent may be termed "raw waste."

4. The fourth scheme relies principally upon internal recycle, with internal or external storage facilities to hold surge flows due to grade changes and other process upsets. Most of these surge flows are then returned to the process as production equilibrium is again approached, with only a small and sometimes intermittent final waste flow occurring.

Thus, raw waste loads from mills in this subcategory vary widely, depending upon the definition used. Data developed in 1971 illustrate this point. Of 13 mills in this subcategory, raw waste suspended solids varied typically from 2.5 kilograms per metric ton (5 pounds per short ton) to 30 kilograms per metric ton (60 pounds per short ton).

A further example taken from two surveyed mills illustrates the same point, and also emphasizes the effect of grade changes. The first mill utilized extensive internal recycle, as well as recycle of some biologically treated waste water. Its raw waste contained 4.5 kilograms per metric ton of suspended solids (9 pounds per short ton). The second surveyed mill utilized only minimum recycle, and relied upon extensive external solids and BOD_5. Raw waste from the second mill contained a much higher 42 kilograms of suspended solids per metric ton (84 pounds per short ton) while making one grade. After a grade change, its raw waste suspended solids decreased markedly to nine kilograms per metric ton (18 pounds per short ton).

Although no definition of "total raw waste load" fits all cases, the "primary effluent not recycled" probably meets most field conditions as the best definition.

Final effluent flow is a measure of the degree of reuse employed by a given mill. The first surveyed mill employed extensive recycle and used only 4200 liters per metric ton (1000 gallons per short ton) during the four days of the survey. The second mill, which did not employ extensive recycle, used 54,000 liters per metric ton (13,000 gallons per short ton) during the survey.

Longer term data from the 13 mills mentioned above show a wide variation in water usage, primarily as a function of recycle. The typical range among these mills was from 8400 liters per metric ton (2,000 gallons per short ton) to 42,000 liters per metric ton (10,000 gallons per short ton).

As the above discussion indicates, BOD_5 and suspended solids are the two primary pollutants identified in the waste water discharged by this industry. No problems associated with heavy metals have been identified and the

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mills surveyed had low concentrations of such metals. These concentrations ranged from a few parts per billion (ppb) for the more toxic metals such as mercury and chromium, to 0.5 to 1.7 parts per million (ppm) for iron, well within the range of many natural waters. Nor has color been a problem, as substantiated by survey data which show an average color unit loading below two kilograms per metric ton (four pounds per short ton). In common with most most pulp and paper effluents, nutrients discharged by this industry are low in nitrogen and phosphorus. As described in Section VII, these nutrients must usually be added to promote the necessary activity within biological treatment systems for the removal of BOD_5.

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SECTION VI

SELECTION OF POLLUTANT PARAMETERS

WASTE WATER PARAMETERS OF SIGNIFICANCE

A thorough analysis of the literature, mill records, sampling data which has been derived from this study, and the Corps of Engineers permits demonstrates that the following constituents represent pollutants according to the Water Pollution Control Act for the subcategories under study:

BOD
suspended solids
pH

RATIONALE FOR SELECTION OF IDENTIFIED PARAMETERS

Biochemical Oxygen Demand (5-day, 20°C)

This parameter is a measure of the amount of biologically degradable organic matter which is present in the waste stream. Failure to substantially reduce the amount of BOD_5 in the waste stream before discharge to receiving waters would adversely affect water quality by consuming large amounts of dissolved oxygen. Although the amount of BOD_5 per ton of product in the discharge from an industrial process varies to a significant degree between mills, its treatability is essentially constant. Measurement of BOD_5 requires uniform procedures and trained personnel. It is difficult to use as a control indicator of waste treatment performance because of the five day test period which is required.

Suspended Solids

Building paper effluents contain appreciable organic matter in solution. However, suspended solids can represent up to 30 per cent of the total BOD_5. Suspended solids are those solids which can be removed from the waste stream by sedimentation in a quiescent zone, and are usually determined in the laboratory by filtration. Coarse and floating matter is not included in an analysis of suspended solids. Removal of suspended solids, including biological solids, substantially reduces both the organic and inorganic pollutant load otherwise existent in the effluent from a mill.

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pH

The effluent from a typical biological treatment process will normally have a pH in the range of 6.0 to 8.5, which is not detrimental to most receiving waters. However, the application of some technologies for the removal of solids and trace organics can result in major adjustments in pH. The effluent limitations which are cited insure that these adjustments are compensated prior to final discharge of treated wastes in order to avoid harmful effects within the receiving waters.

OTHER PARAMETERS INDICATING PRESENCE OF POLLUTANTS

Both COD and TOC are indicators of the presence of pollutants and of the efficienceies of the treatment and control technologies being applied. Therefore, effluents from treatment facilities should be monitored for each of these parameters. Both COD and TOC are a measure of organic and some inorganic matter in the waste stream. As such, they are more inclusive than BOD_5. Unfortunately, no consistent ratios have been established within the building paper industry between BOD_5 and these other two parameters. However, properly developed COD and TOC results can be an effective control indicator of waste treatment performance since tests can be completed rapidly and can be generally related to BOD_5 within a given mill.

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SECTION VII

CONTROL AND TREATMENT TECHNOLOGIES

SUMMARY

Waste waters discharged from mills in the building paper and roofing felt industry to receiving waters can be reduced to required levels by conscientious application of established in-plant process loss control and water recycle measures and by well designed and operated external treatment facilities.

This section describes both the in-plant and external technologies which are either presently available or under intensive development to achieve various levels of pollutant reduction. External technology is used to treat the residual waste concentration levels to achieve the final reduction of pollutants discharged to the environment.

IN-PLANT MEASURES

Recovery and Recycle Concepts

Generally, mills that reduce effluent volume through recycle reduce raw waste pollutant loads concommitantly. As discussed in Section V, in some cases a mill may employ extensive suspended solids removal equipment internally, reusing both the clarified water for manufacture and the recovered solids in the product, whereas another mill depends on an extensive primary clarifier for suspended solids removal. This study indicates that similar reductions in pollution loads are achieved by both methods of treatment.

Large quantities of water are necessary to form a sheet of paper. Typically, the fibrous stock is diluted to about 0.5 percent consistency before entering the paper machine itself. Such dilutions are necessary in order to provide uniform dispersion of the fibers in the sheet forming section. Most of this water must be removed in the wet end of the machine since only a small amount of moisture, typically five to eight percent by weight, is retained in the product at the dry end.

After leaving the forming section of the machine, the sheet of paper or board contains about 80 percent moisture. A press section employing squeeze rolls, sometimes utilizing vacuum, is used to further reduce moisture to a level of about 60 percent. The remaining moisture is evaporated by steam-heated drying rolls.

Water leaving the forming and press sections is called white water, and approximates 104,325 liters per metric ton (25,000 gallons per short ton) of product. Due to recycling, only a relatively small portion of the total is wasted. Typically, in a mill utilizing extensive recycle, only 2087 to 20,865 liters of white water per metric ton (500 to 5000 gallons of white water per short ton) is discharged from the system.

Recycling of this white water within the stock preparation and wet end of the papermaking machine has long been practiced in the industry. However, in recent years very extensive reuse of treated white water has been achieved. The replacement of fresh water with treated white water is the mechanism by which final waste water volume is reduced. It has been demonstrated that with a closed water system the concentration of solids increases significantly to a high level at which plateau it remians, varying only plus or minus lo to 15 percent. Thus, a significant result of total or near total recycle of process water is that dissolved solids, derived primarily from raw materials, are removed from the process water system via the product manufactured rather than in the waste stream.

Problems are experienced, however, as near total recycle of process water is approached. It appears, though, that the production process and product quality of mills in the building paper industry, and particularly those manufacturing roofing felt paper, are such that with good system design these problems can be overcome. This posture is supported, to some extent, by a report from one mill in the industry. In this instance both in-plant and external biological treatment facilities, using the activated sludge process and final chlorination, were installed. After a year of operation, the mill is near a decision to eliminate their discharge to the environment and operate a completely closed process water system.

Saturated roofing felt mills have a water use requirement which is independent of that for the papermaking process. This water is essentially cooling water that becomes contaminated by the granular particles used to coat the saturated felts. The cooling water is applied across the festooned sheet immediately after it passes through the hot liquor asphalt saturation bath. This study indicated that there is no measurable contamination of the water due to its contact with the hot asphalt. The volume required depends entirely on the type of showers used and therefore varies over a wide range, perhaps as low as 209 liters per metric ton (50 gallons per short ton) to as high as 4173 liters per metric ton (1000 gallons per short ton) of paper saturated. There are mills that segregate this water and convey it to a settling pond for the removal of readily settleable suspended solids. However, in order to reuse it as cooling water it is necessary to employ a cooling tower in order to achieve the reduced water temperature necessary for the process application. The success of this recycle system, on a year-round basis, is not well documented since the reduction in pollution load that can be achieved does not necessarily warrant the capital investment, increased operating costs, and potential loss of production inherent in the operation of such a system. Those systems that have been installed have not been operated on a continuous basis by virtue of the weather-dependent nature of a cooling tower.

In-Plant Recovery Equipment

Most mills employ a save-all to recover fibrous and other suspended solids from the process water of which there are three principal types. One is the gravity or vacuum drum type which employs a rotating screen-covered drum immersed in a vat containing the waste water. The water passes through the drum, leaving a mat of fiber which is removed continuously for reuse. The vacuum disc filter is another type of save-all which utilizes a series of screen-covered discs on a rotating shaft immersed in the vat. Both types filter the white water through a filter mat; however, the disc type has the advantage of greater filtering area or capacity per unit volume. The filtering medium in each case is provided by a side-stream of "sweetener" stock added to the influent to act as a filtering mat for the removal of suspended solids. The recovered fiber and sweetener stock is returned for reuse directly to the stock system. A third type is a stationary bar screen with very fine slots between the bars which has in recent years been employed by mills in this industry for the recovery of fiber from the process water system. There is a significant economic advantage in this type of system. However, the quality of the effluent is not as high in terms of suspended solids as that generated by vacuum filters.

All or a part of the effluent from a save-all may be discharged directly to a sewer, but most mills reuse a significant portion for such services as ( ):

1. Machine showers
2. Stock cleaner elutriation
3. Pump and agitator seals
4. Vacuum pump seals
5. Wash-ups
6. Consistency regulation dilution

Machine Showers

Machine and felt showers are used in both the forming and press sections to clean the wire, felts, and other machine elements subject to contact with the stock. Formerly, large volumes of fresh water were used for this purpose, but in recent years, attention has focused on the use of recycled white water. However, a suspended solids content of less than 120 milligrams per liter (one pound per thousand gallons) is generally required to avoid plugging of shower nozzles. Concurrently, the use of high pressure (up to 52 atm. or 750 psig), low volume showers using fresh water has increased. These are employed where product, operability, cleanliness, or other factors mitigate against the use of white water showers. These high pressure showers are operated on a time cycle, so that flow occurs only a small percentage, 10 to 20 percent, of the time.

Whether recycled water or lower volumes of fresh water are used for showers, a reduction in fresh water usage and its concomitant waste water flow results. Significantly, this reduction also decreases the fiber losses to sewer.

Seal Water

Vacuum pumps are essential to the paper forming process as presently practiced to provide a vacuum source to accelerate the removal of water from the sheet as formed, and to dry the felts for each pass through the wet end. Most such pumps are of the ring seal type, which requires water to provide a seal between the moving parts of the pump and avoid backflow of air to the vacuum side. Water used for this purpose must be sufficiently free of suspended solids to avoid plugging of the orifices or other control devices used to meter it to the pump. Further, it must not be corrosive to the mechanical parts of the pump, and it must be relatively cool (typically less than 32°C (90°F)) to permit development of high vacuums of 0.67-0.74 atm. (20-22 in. Hg.) For lower vacuum requirements 0.17-0.40 atm. (5-12 in. Hg.), somewhat higher temperatures are permissible.

Seal water is also used on packing glands of process pumps, agitators, and other equipment employing rotating shafts. It cools bearings, and lubricates the packing, and minimizes leakage of the process fluid. Even though the amount of water used per packing is small -- generally in the range of 1.86 to 11.34 liters per minute (0.5 to 3 gpm) -- the total usage is quite extensive because of the large number of rotating shafts required in the processes. The total usage may approximate 4173-8346 liters per metric ton (1000-2000 gallons per short ton) of product. Methods used to control and reduce the quantities of water required include proper maintenance of packings and flow control of individual seal water lines.

As more intensive recycle is employed the significance of the quantity of seal water used for all purposes in the mill increases in terms of waste water volume. The use of mechanical seals has reduced the amount of seal water, but they have so far not proven satisfactory in terms of maintenance and reliability for many applications.

The replacement of fresh water with clarified waste water in the building paper industry is dependent largely on maintaining a level of suspended solids in the recycled seal water at 120 mg/l or less. The vacuum required on the paper machines in these mills indicates that a seal water temperature of 49°C can be tolerated. The limits to recycle in the water use area will be more completely documented as more mills develop reuse systems.

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Stock Cleaning Systems

A majority of mills in this industry employ a stock cleaning system that dates back many years, the riffler. This is a simple device that removes sand, grit, metals, and other readily settled contaminants from the stock slurry. This system subjects the process water system to insignificant, if any, fresh water requirements and satisfies the cleaning needs of the production quality. The contribution to the waste water load is also small since the solids removed from the stock can be removed at intervals from the bottom of the riffler trough, generally at most once a week. This material is disposed of by trucking to a plant-owned or municipal land disposal area.

If cleaning at the machine is practiced, flat bed slotted plate vibrating screens are generally employed. This method of cleaning, as with a riffler, has been in use for many years. Again, rejects are removed in a relatively dry state for truck disposal and the impact on the waste water generated by the mill is negligible.

The trend toward replacement of these older cleaning systems with more modern equipment will increase in this industry as labor and maintenance costs exceed the increased power costs associated with the new equipment. With the newer cleaning equipment there is potential for increased quantities of rejects and, more importantly, fiber discharged to the sewer. This phenomenon has already been experienced by many mills in the waste paperboard industry. The effect on the waste water load generated can be minimized or eliminated by the inclusion of a well designed rejects handling system along with an improved cleaning system. The effectiveness of these systems becomes more significant to a mill as it approaches near total recycle of process water. In fact, under this condition it becomes of paramount importance since rejects cannot escape from the mill in the waste water, and therefore build up in the system unless removed in a relatively dry state by an adequate rejects handling system.

Cooling Water

Cooling water is used for bearings, particularly in older mills using sleeve bearings instead of the anti-friction bearings employed in new or rebuilt mills. Cooling water is not contaminated and can be collected and reused either directly (after heat removal), or indirectly by discharge into the fresh water system, if heat buildup is not a problem. Similarly, water used to cool brake linings in paper rewind applications may be reused. Water used to cool condensate from the steam dryers can also be reused, but because of high heat loads cooling of this water by cooling towers or other means would usually be necessary. None of the mills surveyed in this study cooled this water. However, one mill surveyed returned dryer condensate directly to the feed water heater at the boiler plant under 1.20-1.34 atm. (three-five psig) pressure, thereby reducing the cooling water requirement. This approach could be used more generally where dryers are operated at pressures above 1.34 atm. (five psig).

While reduction of cooling water usage does not, per se, reduce the level of pollutants in the waste water, it does reduce the volume of waste to be treated, thereby reducing the capital and, in some instances, operating cost of waste treatment facilities.

Asphalt Cooling

The volume of waste water generated in the felt saturating cooling process is entirely dependent on the type of shower nozzles used to spray the sheet. A very high reduction in water requirements with increased cooling efficiency -- i.e., temperature drop per unit time -- has been achieved with special nozzles. The need to settle the waste water generated by this process is established, and the ability to recycle after cooling has been demonstrated. However, be cause of its low pollutant load, the need to recycle this waste after settling versus discharge to the environment appears to be an issue to be determined on an individual mill basis.

EXTERNAL TREATMENT TECHNOLOGY

Waste treatment requirements do not vary appreciably among mills in the building paper industry. Although there are variations in concentrations and specific waste constituents, the general classes of compounds which can be expected to occur in their wastes derive from the pulping of wood fiber or repulping of waste fiber and are, thus, characteristic of them all. These substances are dissolved organic components of wood and cellulose degradation products. They make up the bulk of the oxygen demanding wastes of this subcategory. The pulping of rags and/or asbestos adds to the waste load generated. In addition, other compounds such as adhesives, sizing material, and resinates are used by the industry depending on product. The residual of all of these substances in the waste load, or combinations of them, appears to be amenable to the various biological treatment processes used by the industry.

Removal of Suspended Solids

The physical process of removing suspended organic and inorganic materials, commonly termed primary treatment, is generally accomplished by sedimentation. Screening ahead of treatment units is necessary to remove trash materials which could seriously damage or clog succeeding equipment. Automatically cleaned screens, operating in response to level control, are commonly employed and represent preferred practice.

Primary treatment can be accomplished in mechanical clarifiers or sedimentation lagoons. Although the latter enjoyed widespread use in the past, the large land requirement, coupled with inefficient performance and high cost for cleaning, has made them less popular in recent years (7).

The most widely used method for sedimention in this industry is the mechanically-cleaned quiescent sedimentation basin (7). Large circular tanks of concrete construction are normally utilized with rotating sludge scraper mechanisms mounted in the center. Effluent usually enters the tank through a well which is located at the center of the tank. Settled sludge is raked to a center sump or concentric hopper and is conveyed back to the process system. Floating material is collected by a surface skimmer attached to the rotating mechanism and discharged to a hopper. This material may be brought back to the process or carried to land disposal.

A properly designed and installed mechanical clarifier is capable of removing over 95 percent of the settleable suspended solids from the effluents produced. The removal efficiency of this fraction of the total suspended solids is the true measure of performance for this device since it cannot be expected to separate those solids which will not settle under the most favorable conditions.

Because of the biodegradable nature of a portion of the settleable solids present in the effluents of these mills, clarification results in some BOD reduction.

BOD Reduction

BOD reduction is generally accomplished by biological means, again because of the relative biodegradability of most of the organic substances in the waste. Advances in reduction of internal losses and recycling of process water have increased BOD concentrations in the waste to be treated. However, this, in general, seems to improve the removal efficiency of the process. While BOD reduction by biological methods represents common practice today, it should be understood that other methods discussed under "Advanced Waste Treatment" may, in the future, avoid the need for biological treatment to reduce BOD.

Current biological treatment practice includes the use of very large storage oxidation basins, aerated stabilization basins, or the activated sludge process and modifications thereof. The storage oxidation basin and the aerated stabilization basin because of their large land requirements have not found wide application in this industry. Most of the mills are located in relatively populated areas with minimum land availability, therefore, the activated sludge process has had wider acceptance.

The land requirements of the oxidation basin are due to the fact that it is a relatively low-rate process. Because of the availability of land, and the warmer climate which helps to maintain consistent biological activity, most natural oxidation basins are found in the southern states (7). Design loading rates of 56 kilograms BOD per hectare per day (50 pounds BOD per acre per day) for natural oxidation basins to achieve 85-90 percent removal in warm climates have been reported (8).

By installing aeration equipment in a natural basin, its ability to assimilate BOD per unit of surface area is greatly increased. The aerated stabilization basin originally evolved out of the necessity of increasing performance of existing natural basins due to increasing effluent flows and/or more stringent water quality standards. Due to its inherent acceleration of the biological process, the aerated stabilization basin requires much less land than the natural stabilization basin and because of the long reaction period less nutrient addition than that required for activated sludge. Typically, 0.21 hectares per million liters (two acres per MGD) of the aerated stabilization basin compared with 4.8 hectares per million liters (40 acres per MGD) for natural basins for equivalent treatment levels (9). Detention times in the aerated stabilization basin normally range from five to 15 days, averaging less than 10 days.

Due to the relatively long aeration time, the buildup of sludge solids is considerably less than for higher rate processes, particularly where primary clarification is employed. Typical rates are 45.4 to 90.8 grams (0.1 to 0.2 pounds) of sludge generated for each 454 grams (pound) of BOD removed (7). The sludge is removed as formed by endogenous respiration, sludge loss in the effluent, and sedimentation within the aeration basin. However, discharge of untreated waste to an aerated stabilization basin without prior clarification can result in a buildup of sludge which after a period of time will impede its efficiency.

Most mill wastes are deficient in nitrogen and phosphorus, therefore, the addition of nutrients to the aeration basin is generally practiced. Reported optimum ratios of BOD to nitrogen are 50:1 with four days aeration, and 100:1 with 10-15 days aeration (8).

Aeration is normally accomplished using either gear-driven turbine-type aerators, direct-drive axial flow-pump aerators, and, in a few cases, diffused aerators. Oxygenation efficiencies under actual operating conditions range from 0.61 to 1.52 kilograms of oxygen per kilowatt per hour (one to 2.5 pounds of oxygen per horsepower per hour), depending on the type of equipment used, the amount of aeration power per unit lagoon volume, basin configuration, and the biological characteristics of the system. A dissolved oxygen level of 0.5 mg/l remaining in the lagoon liquid is required to sustain aerobic conditions (10). Design experience indicates that 1.1 to 1.3 kilograms of oxygen per kilogram BOD_5 (1.1 to 1.3 pounds oxygen per pound BOD_5) are required to maintain adequate DO for waste oxidation and endogenous respiration at the biological mass produced.

Although the activated sludge process has been employed for many years to treat domestic sewage, it was first applied to pulp and paper mill waste in 1953 (8), and in the building paper industry only very recently. The process is similar to the aerated stabilization basin except that it is much faster, usually designed for four to eight hours of total detention time. The biological mass grown in the aeration tank is settled in a secondary clarifier and returned to the aeration tank, building up a large concentration of active biological material. Since there is approximately 2000-4000 mg/l of active sludge mass in the aeration section of this process, as opposed to 50-200 mg/l in the aerated stabilization basin, dissolved and suspended organic matter are removed much more rapidly, greatly reducing necessary tank volume as well as required detention time. Since biological organisms are in continuous circulation throughout the process, complete mixing and suspension of solids in the aeration basin is required. The active microbial mass consists mainly of bacteria, protozoa, rotifers, fungi, and cyntomnemotodes. Because the process involves intimate contact of organic waste with biological organisms, followed by sedimentation, a high degree of BOD and solids removals are obtained.

The contact stabilization process is a variation of activated sludge wherein two aeration steps are utilized rather than one. First, the incoming waste is contacted for a short period with active organisms prior to sedimentation. Settled solids are then aerated for a longer period to complete waste assimilation. Contact stabilization has been applied successfully, however, conventional activated sludge has found more accepted use in this industry.

The secondary clarifier in the activated sludge process performs the function of sedimentation of the active microbial mass for return to the aeration tank. Rates of about 211 liters per day per square meter (600 gallons per day per square foot) have been suggested (9). For a more conservative approach, secondary clarifier rise rate should not exceed 141 liters per day per square meter (400 gallons per day per square foot) (7). It is advisable to design secondary clarifiers for lower loading rates as periodic episodes of sludge bulking or poor sedimentation arising from variable loading and aeration can occur.

Due to the fact that the sludge volume is greatly reduced in the activated sludge system, the endogenous respiration of the sludge mass is considerably lessened. Thus, there are additional quantities of excess sludge, one kilogram of excess sludge per kilogram of BOD (one pound of excess sludge per pound of BOD), which must be disposed of.

As in the case of the aerated stabilization basin, aeration can be accomplished by mechanical or diffused aeration. The more efficient and more easily maintained mechanical method is generally preferred by the industry. Oxygen requirements where activated sludge processes are utilized are in the range of one kilogram of oxygen per kilogram of BOD_5 (one pound of oxygen per pound of BOD_5) removed.

Short detention times and low volumes make the activated sludge process more susceptible to upset due to shock loads. When the process is disrupted, several days are usually required to return the biological activity and high BOD removal rates back to normal. Thus, particular attention is required to avoid such shock loads in mills utilizing this process.

A flow diagram of waste treatment at a building paper mill is shown in Figure 4.

SLUDGE DEWATERING AND DISPOSAL

Due to their high organic content, the dewatering and disposal of sludges resulting from the waste treatment of mill effluents can pose a major problem and cost more than the treatment itself. In early practice, these sludges were placed in holding basins from which free water from natural compaction and rainfall was decanted. When a basin was full, it was abandoned, or, if sufficient drying took place, the cake was excavated and dumped on waste land. In this case, the basin was returned to service.

Odor problems from drying, as well as land limitations, have demanded the adoption of more advanced practices. These are covered in detail in NCASI Technical Bulletin No. 190 (11) and are described briefly below.

Depending on the performance of dewatering equipment, in some cases it is either necessary or desirable to prethicken sludges. This is accomplished by gravity thickeners of the "picket-fence" type or by providing a high level of sludge storage capacity in mechanical clarifiers. Small mills sometimes employ high conical tanks which serve as both storage tanks and thickeners. These have side wall slopes in excess of 60° but contain no mechanism.

Sludges from building paper mills can generally be thickened to a consistency in excess of four percent dry solids by prethickening. If activated sludge from secondary treatment is included, this figure can be somewhat lower.

Vacuum filters are in use for dewatering sludges and produce filter cakes ranging from 20 to 30 percent solids. Observed capacities for the poorly filterable sludges can generally be about doubled by chemical conditioning

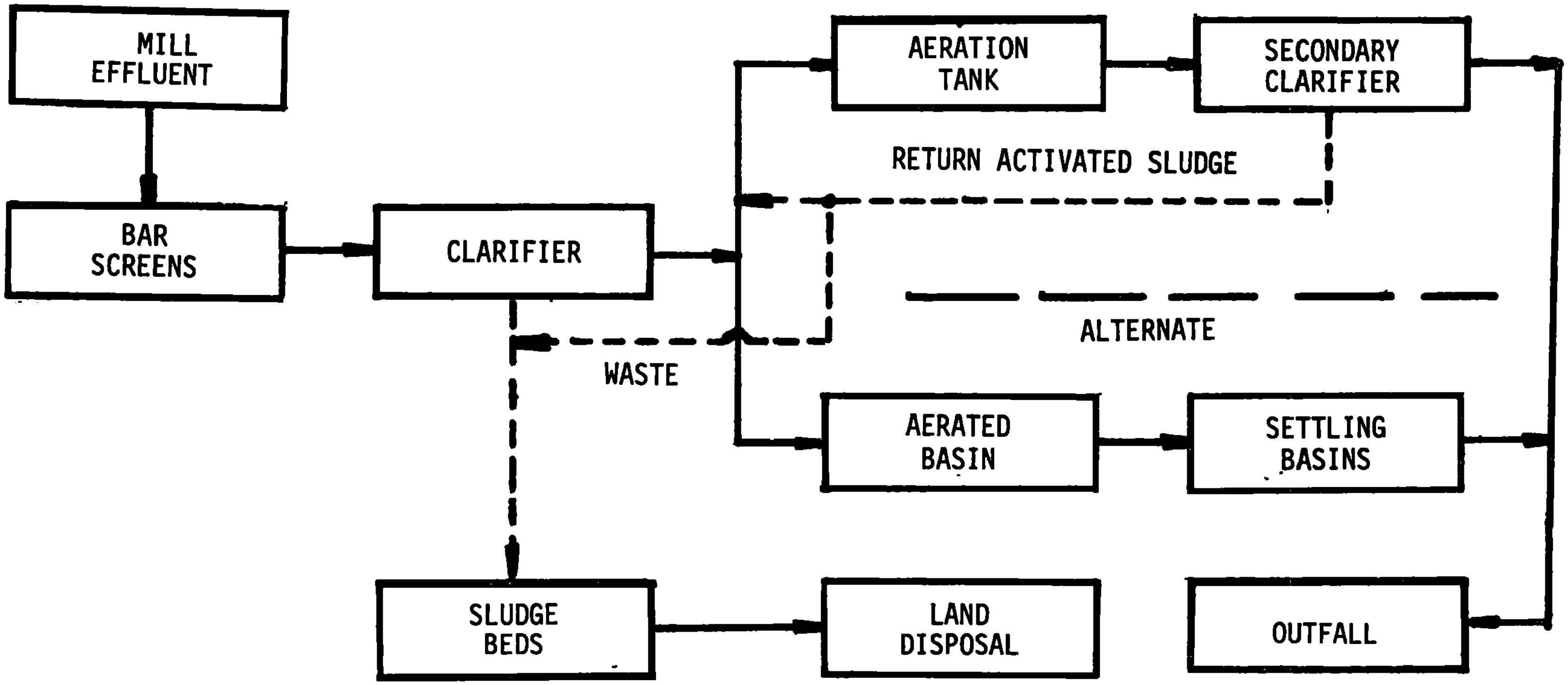


FIGURE 4

EFFLUENT TREATMENT AT

BUILDING PAPER MILLS

with ferric chloride, alum, or polyelectrolytes at a cost of from $2.72 to $4.54 per metric ton ($3.00 to $5.00 per short ton) of dry solids. Such treatment is generally necessary when activated sludge is included in the sludge to be dewatered since the addition of 20 percent of this material on a dry solids basis can reduce filtration rates as much as 50 percent.

Complete vacuum filter installations, including all accessories, range from $4306 to $5382 per square meter of filter area ($400 to $500 per square foot of filter area). Although a number of different types of filters are in service, coil or belt types are the most popular among recent installations. At one mill using coil filters, average cake content of 23 percent was reported, with an influent sludge concentration of 3.3 percent. Loading rates averaged 27.37 kilograms solids per square meter of filter area per day (5.6 pounds solids per square foot of filter area per day).

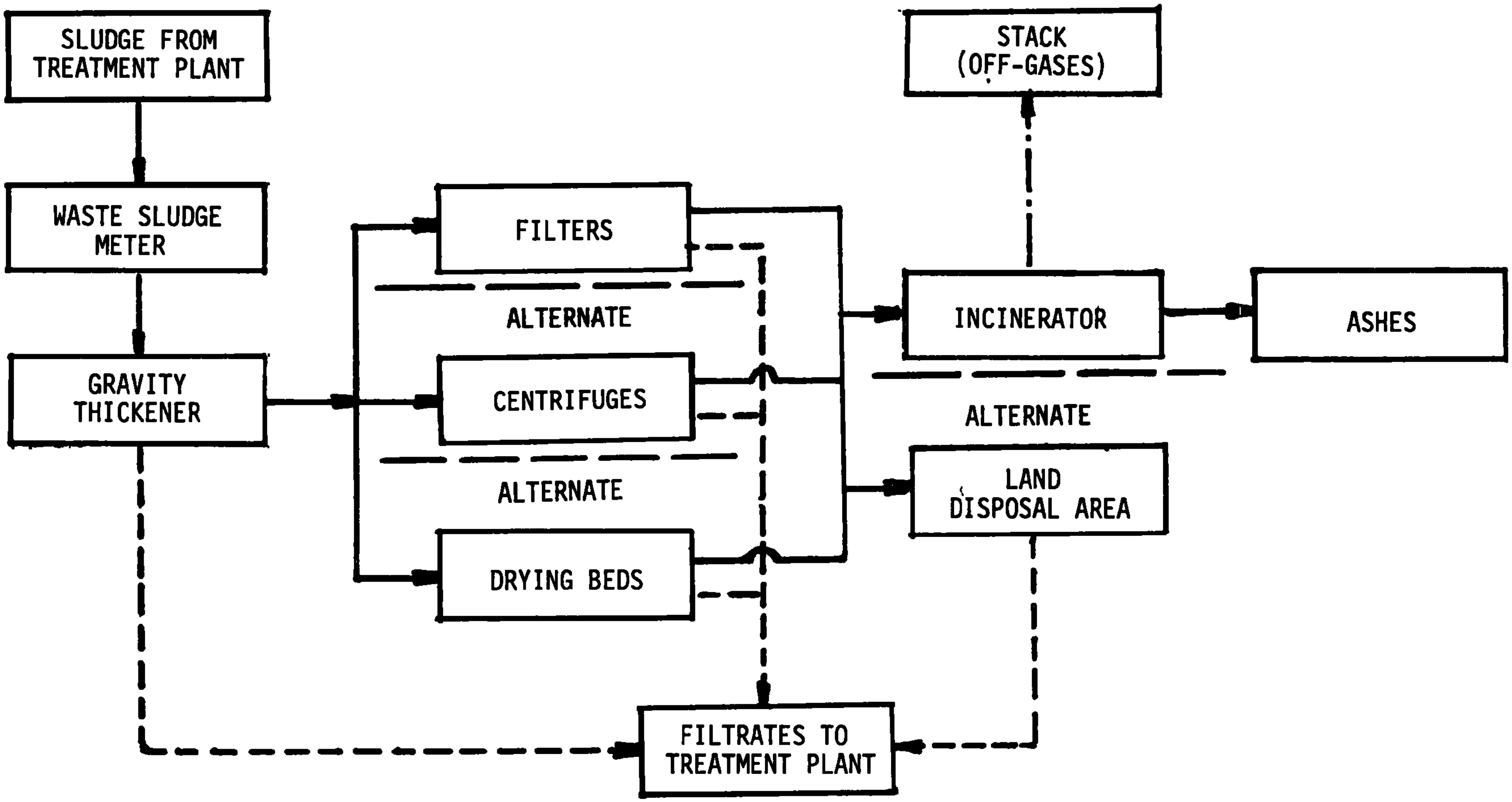
Centrifuges are also used for sludge dewatering. In practice, the higher the consistency of the feed, the more effective they are in terms of solids capture in relation to through-put as well as to reduced cake moisture. Moisture is generally lower than in cakes produced by vacuum filters. Cakes range from 25 to 35 percent dry solids content and are in a pelletized easily handleable form. To operate effectively, centrifuges must capture in excess of 85 percent of the solids in the feed stream.

Centrifuges cost from $106 to $159 per liter per minute ($400 to $600 per gpm) of feed capacity. At a two percent solids feed consistency, this is equivalent to 97.6 kilograms of dry solids (215 pounds of dry solids) daily at 90 percent capture.

Although drying beds are employed for dewatering sludges, they are not constructed as elaborately as are those employed for sanitary sewage. They generally consist only of multiple earthen basins without a complex underdrain system.

Detailed experiments on this method of dewatering sludge set forth parameters of good practice and area requirements (12). The latter vary naturally with the climate, although adjustments as to the depth of sludge deposited and its initial moisture content are also involved. The most effective depth is less than one foot.

Sludge generated by mills in this industry can be removed for disposal on the land as soon as it becomes "spadeable" or handleable with earth moving equipment, which is about 25 percent solids content. Further drying occurs upon the land if initial drying is sufficient. A sludge dewatering and disposal operation is shown in Figure 5.



SLUDGE DEWATERING AND DISPOSAL

FIGURE 5

COLOR REMOVAL

The building paper and roofing felt subcategory has practiced the use of biological treatment on its waste water to a relatively limited extent. Therefore the basis for demonstrating the applicability of advanced waste treatment concepts, including color removal, in the industry is not readily established. It appears that, in view of the industry's potential for the development of total or near total recycle of process water, advanced treatment concepts would be most valuable as a tool to control the concentrations of dissolved solids and color buildup attending close-up to levels that can be tolerated by the process system and product quality.

It is in this context that the performance of advanced waste treatment studies are presented below. This data was generated as applied in the pulp and paper industry and the municipal waste treatment field. However, due to the similarity of waste constituents it is apparent that the technology described may be applicable to the building paper and roofing felt subcategory.

For more than twenty years, the pulp and paper industry has been actively engaged in research for the reduction of color, primarily in kraft mill effluents. These efforts have been directed particularly to those cases where color discharge has created aesthetic problems due to the high clarity of the particular receiving waters. The bulk of the research has concentrated on development of lime precipitation techniques because of the relative economics of this compared to other techniques, and the familiarity with and availability of lime handling systems in kraft mills. The overriding initial problem with the lime approaches was the generation of large volumes of gelatinous, difficult to dewater sludges. Several schemes were developed to overcome this problem and full-scale systems have been installed in recent years. Color removal efficiencies of 85 to 90 percent are being achieved. In two unbleached kraft mills, the lime sludge is recovered, dewatered, and incinerated in the lime kiln.

Considerable research has been performed on other color removal techniques, principally activated carbon, reverse osmosis, and alum precipitation. Alum precipitation was found to be economical in one instance where alum mud from the nearby manufacture of alum is the primary chemical source. A full-scale installation of this system is planned.

Activated carbon and reverse osmosis have been considered as polishing treatment in conjunction with other processes, for producing a highly treated effluent for discharge. Additionally, they have been considered as a treatment process producing an effluent suitable for recycling. The latter concept appears promising. However, full-scale testing has not been tried to date.

Sources of Color

In the various chemical pulping processes, lignin and lignin derivatives are solubilized and removed from the wood during the cooking process. The spent cooking liquors, containing these highly colored compounds, are removed from the pulp in a washing sequence following the cooking process. The wash water is highly colored. In the kraft process, however, this wash water is sent to the recovery area where the cooking chemicals are recovered and the organic materials are burned in the recovery furance. The washing and recovery operations are efficient; however, losses of cooking liquor and the discharge of evaporator condensate result in a reddish brown effluent. Additionally, most unbleached kraft mills discharge the water removed from the pulp on the last operation before going to the paper mill known as the unbleached stock decker. The discharge from this operation is the most significant colored effluent from the production of unbleached kraft pulp. Average values of color discharged from kraft and NSSC pulping and from unbleached kraft papermaking operations are shown in Tables 1 and 2 (9).

Lime Treatment

The development of the lime color reduction process has been traced by several authors (13)(14)(9)(7). A brief review of this history is in order. In the early 1950's, Moggio reported the results of a laboratory program in which several coagulants were tested for their effectiveness in reducing the color of kraft pulping and bleaching effluents (15). This investigation measured the effectiveness of alum, ferric sulfate, lime, sulfuric acid, char, clay, activated carbon, activated silica, ferric chloride, chlorinated copperas, phosphoric acid, waste pickle liquor, and a barium alumina silicate compound. In general, Moggio found that good color reduction could be obtained with several of the agents. It was concluded, however, that the cost of chemical treatment was prohibitive with the exception of lime treatment which afforded the possibility of lime recovery in the normal mill process. In addition to the prohibitive costs of chemical treatment, a large volume of difficult to dewater gelatinous sludge formed in the chemical treatment processes was cited as a major problem.

Based on the results of this early work, research continued towards development of the lime precipitation process. The overriding problem in this work continued to be the difficulty of dewatering the lime-organic sludge. Specific studies were conducted for resolving the sludge problem with limited success (16)(17). In an investigation of the surface reaction process (18)(19)(20), in which effluent was filtered through a precoat of hydrated lime, it was successful in the laboratory. However, operational problems with the pilot plant scale system forced this process to be abandoned.

Continuing efforts to improve the dewatering of the lime sludge led to

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TABLE 1

VALUES FOR COLOR DISCHARGED FROM VARIOUS PULPING PROCESSES (9)

Effluent	Pounds of Color Units* Per Ton of Product
Kraft Pulping	50 to 300
Kraft Papermaking	3 to 8

* Pound of color units (APHA color Units) x 10^{-6} x 8.34

TABLE 2

UNIT PROCESS FLOW AND COLOR DISTRIBUTION IN INDIVIDUAL KRAFT PULPING EFFLUENTS (9)

	Flow Thous. Gal/Ton	Color Units
Paper Mill	11.4	10
Pulp Mill	0.9	520
Evaporators	0.1	3760
Recovery	0.2	20

consideration of using large dosages of lime for color reduction. It was believed that a large quantity of rapidly draining material would reduce the effect of the organic matter on dewatering. This thinking led to the development and patenting of the "massive lime" process by the National Council for Air and Stream Improvement (21). In this process the mill's total process lime is slaked and reacted with a highly colored effluent stream. The lime sludge is then settled, dewatered, and used for causticizing green liquor. During the causticizing process, the color bodies are dissolved in the white liquor and eventually burned in the recovery furnace. A flow diagram of the patented process is shown in Figure 6.

Although the massive lime process had been demonstrated as an effective color removal system, the process was not taken beyond the pilot stage for several years. The first large scale application of the process was at the Springhill, Louisiana mill of International Paper (22). This plant was operated from February, 1970 to August, 1971. The results of this operation are presented in a later section.

The massive lime process, as developed, relied on high concentrations of lime (on the order of 20,000 mg/l). Because of this, only a relatively small effluent stream could be treated with the quantity of lime used for causticizing green liquor. Additionally, the use of this process required modifications to the recovery system. These restrictions and the need for color removal from total unbleached kraft mill effluents led to the independent development of three lime precipitation processes employing a "minimum" lime dosage for decolorization followed by various methods of sludge disposal or recovery. Two of these systems are now in full-scale operation on the total mill effluent from the production of unbleached kraft pulp at Interstate Paper Co., in Riceboro, Georgia and Continental Can Company in Hodge, Louisiana (23)(24). The Hodge mill also produces NSSC. Lime dosages at both mills are about 1000 mg/l. At the Interstate mill, the lime sludge is not recovered. Continental Can, however, dewaters the lime sludge by centrifuge and recovers the lime in the process lime kiln.

Other Color Removal Systems

Although lime treatment methods have been the only color removal processes installed on a full scale basis to date, research is ongoing for other processes. These include activated carbon, reverse osmosis and other membrane techniques, resin separation, ion exchange, and other coagulation systems.

Activated Carbon

Timpe and Lang (9) have reported on the use of activated carbon in combination with other treatment processes on a pilot scale for the treatment of unbleached kraft mill effluent. The treatment sequences were:

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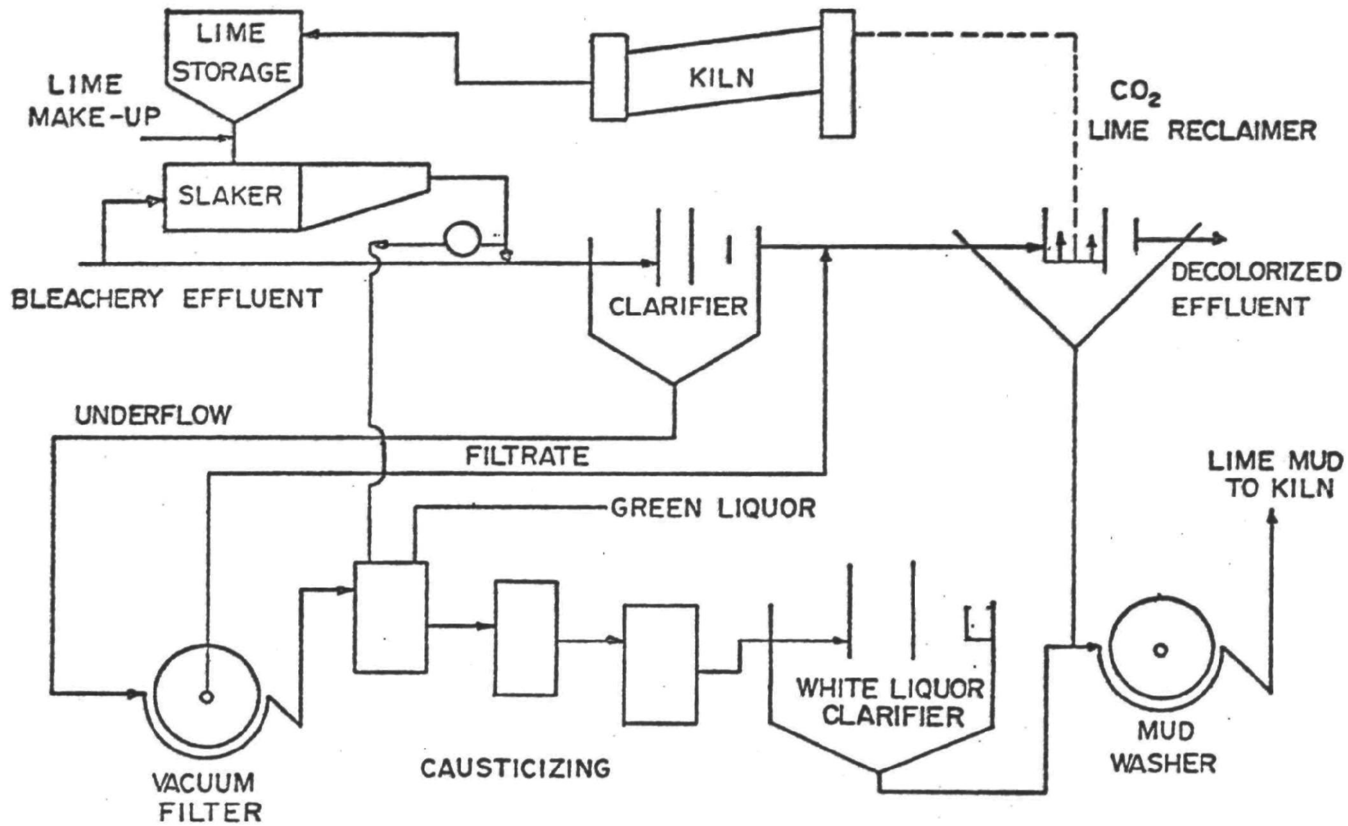

MASSIVE LIME PROCESS FOR COLOR REMOVAL (15)

FIGURE 6

1. Primary clarification; activated carbon
2. Lime treatment; clarification; activated carbon
3. Clarification; biological oxidation; activated carbon

The flow diagram of the pilot system is shown in Figure 7. Two carbon systems were evaluated. The first used four standard down-flow columns for series or parallel operation. The second system is called the FACET (Fine Activated Carbon Effluent Treatment) system and is a multi-stage countercurrent, agitated system with continuous countercurrent transfer of both carbon and liquor from stage to stage. It uses a carbon size between standard granular and powdered classifications. The system is the subject of a patent application.

In the lime-carbon system, lime dosages were from 318 to 980 mg/l CaO, and is referred to by the authors as "micro" lime treatment as compared to the "minimum" lime treatment used by others (22)(23)(24). With these dosages, the authors state that recarbonation of the effluent is unnecessary for reuse of the treated effluent. It should be noted that the intent of this investigation was to treat the effluent to a degree allowing reuse in the mill. In this respect they were not necessarily looking for a combination of systems capable of producing an effluent suitable for discharge.

Smith and Berger (25) investigated the efficiency of activated carbon absorption preceded by massive lime treatment, carbonation, and extended aeration in a batch treatment pilot plant. This process was also evaluated without the extended aeration step.

Thibodeaux and Berger (26) made similar studies on a pilot scale. They investigated the effects of massive lime treatment, biological oxidation, and absorption in granular carbon columns. McGlasson, et al.(27) investigated the effect of activated carbon as a polishing step following biological oxidation and lime treatment. This process was tested on total kraft mill effluent on a semi-pilot plant scale and was also run without the lime treatment step to test the effectiveness of carbon in reducing the effluent color.

Coagulation Techniques

Smith and Christman (58) tested the effects of alum and ferric chloride for the removal of color from kraft mill effluents in the laboratory. Tests were run on both hard and softwoods. The optimum dosage of alum on hardwood wastes was found to be 150 mg/l. A color reduction of 89 percent was achieved from an initial color of 710 units. Softwood kraft effluent was found to require a dosage of 300 mg/l. Ferric chloride coagulation of softwood waste required an optimum dosage of 286 mg/l and produced 87 percent removals.

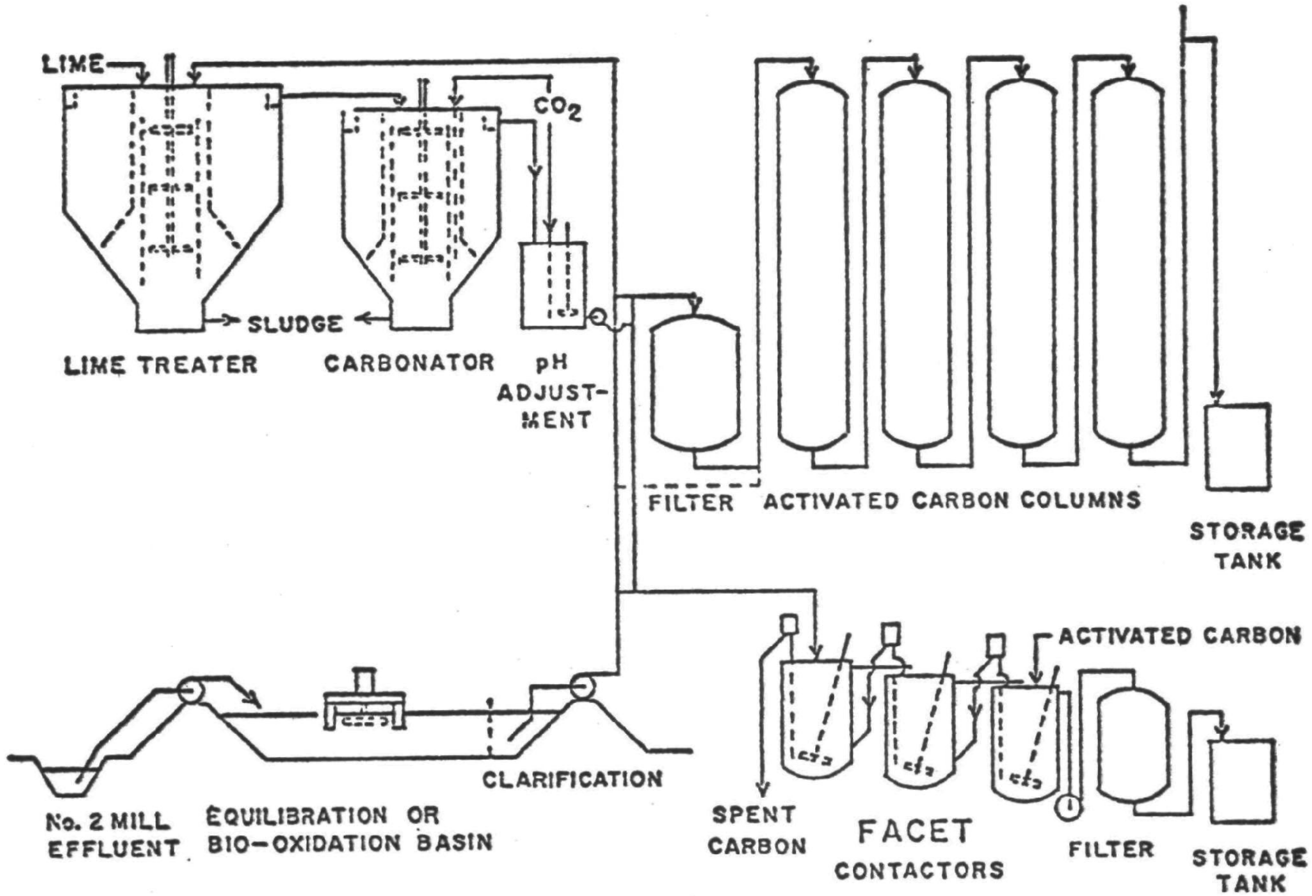

FIGURE 7 - EFFLUENT TREATMENT PILOT PLANT

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Middlebrooks, et al. reported on the laboratory investigation of alum and six organic polyelectrolytes for the removal of color from kraft mill wastewater (28). They report little difference in the performance of the six polyelectrolytes. Alum produced good results, but resulted in approximately three times the volume of sludge. Color removals averaged 95 percent.

Comparison of System Efficiencies

Timpe and Lang (29) report that the biological-carbon treatment sequence utilizing four columns in series reduced color of total kraft effluent to 212 units which they state is too high for reuse in some areas of the mill. This is shown in Table 3. They estimate an additional three columns would be required to produce the goal of 100 color units.

The primary clarification-carbon system tested by Timpe again used four columns. Color was reduced to 185-202 units. This is shown in Table 4. As with the biological-carbon system, it was estimated that an additional three columns would be required to reach 100 color units.

The clarification-lime-carbon system produced the best results of the three systems. In the lime treatment system, the investigators found that color removal increased from 70 percent at a dissolved Ca concentration of 80 mg/l to 86 percent at a Ca concentration of 400 mg/l. Lime dosages ranged from 318 to 980 mg/l. This reduction is shown graphically in Figure 8. Color removal in the carbon columns (2 columns in series) was also found to be dependent on Ca concentration. Color in the effluent remained at about 60 units at calcium concentrations above 80 mg/l. TOC levels after carbon treatment also varied with Ca concentration, remaining fairly constant with Ca concentrations above 80 mg/l. TOC levels after carbon treatment also varied with Ca concentration, remaining fairly constant with Ca concentrations above 40 mg/l. Color removal through the carbon columns in the soluble calcium range of 69-83 mg/l averaged an additional 21 percent, to give an overall reduction of 90 percent. This is shown in Table 5. Water of this quality was considered suitable for reuse.

Operation of the FACET system following lime treatment, as reported by Timpe, produced similar results to the two carbon columns after filtration. This is shown in Table 6.

Smith and Berger (25) report a total color removal in the four stage (lime - carbonation - oxidation - carbon) system of 99.5 percent. In the three stage system (no oxidation) the total removal was again 99.5 percent. This is shown in Table 7.

Thibodeaux and Berger (26) report that the color of unbleached kraft effluent was reduced to 10 and 15 units in two separate pilot runs

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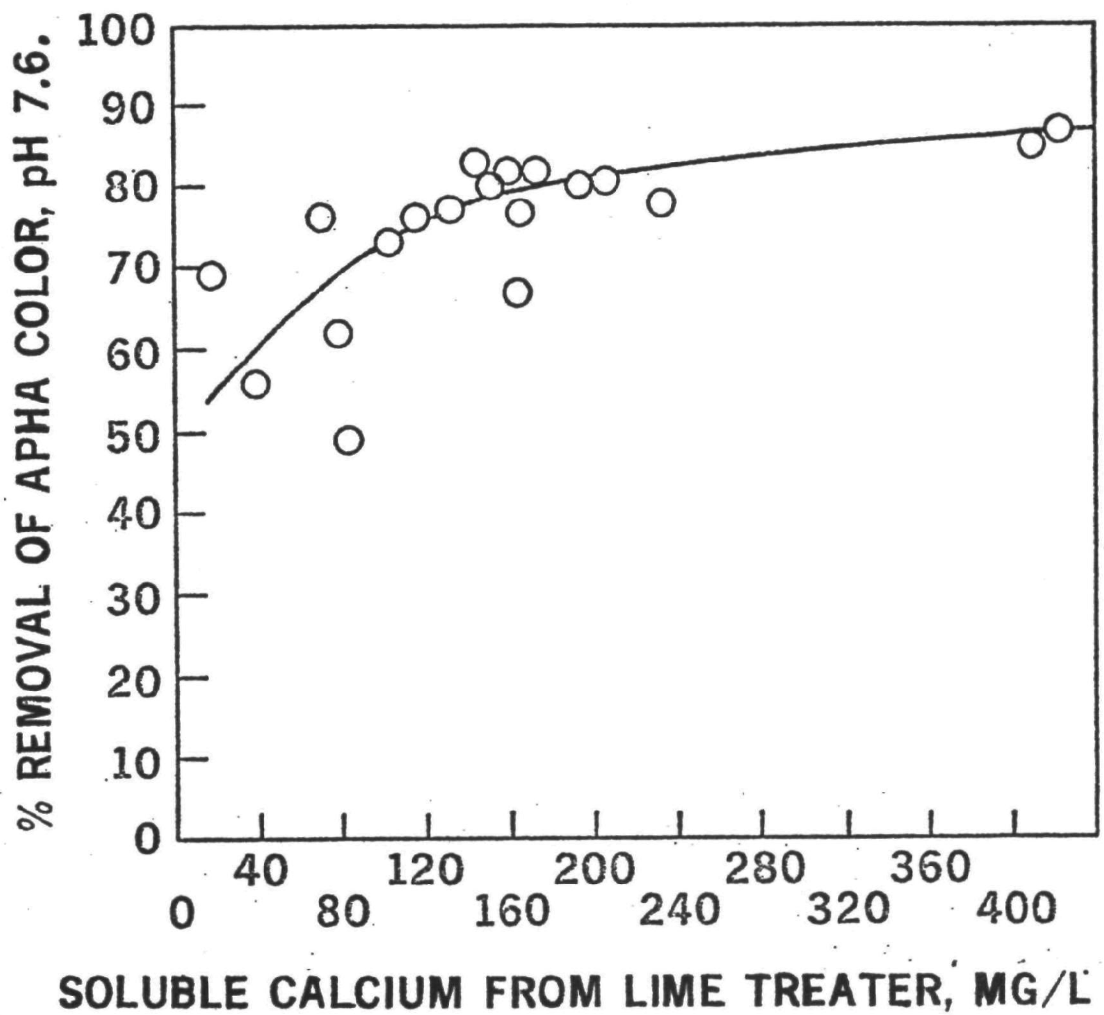

FIGURE 8 COLOR REMOVAL IN LIME TREATMENT AS A FUNCTION OF SOLUBLE Ca IN WATER (29)

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TABLE 3

COLOR REMOVAL IN BIOLOGICAL OXIDATION - CARBON ADSORPTION SEQUENCE AT 15 GPM (2.3 GPM/FT^2) (9)

	Range	Average
Feed to bio-oxidation, APHA CU	430-2500	1100
Feed to carbon, APHA CU	460-1100	740
Product from carbon, APHA CU	42-400	212
Removal by bio-oxidation plus filter,%	-	33
Removal by carbon, % of feed to carbon	-	71
Total removal % feed to bio-oxidation	-	81
Rate of removal by carbon, CU/g hr	0.51-1.00	0.77

Note: Color measured at pH 7.6 after 0.8 micron Millipore filtration.

TABLE 4

COLOR REMOVAL BY PRIMARY CLARIFICATION - CARBON ADSORPTION SEQUENCE (9)

	Trial 1	Trial 2
Flow rate, gpm	10	5
Flow rate, gpm/ft^2	1.42	0.71
Feed to carbon, APHA CU	925	1160
Product from carbon, APHA CU	185	202
Removal by carbon, %	80	83
Rate of removal by carbon, Cu/g hr	0.69	0.46

Note: Color measured at pH 7.6 after 0.8 micron Millipore filtration.

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TABLE 5

COLOR REMOVAL BY LIME TREATMENT - CARBON ADSORPTION SEQUENCE AT SOLUBLE CALCIUM RANGE OF 69 - 83 mg/l (29)

lime dosage, CaO, mg/l	523
pH of feed to carbon adsorption	11.3
flow rate to carbon adsorption, gpm	10
No. of carbon columns	2

Concentrations:	Color, APHA pH 7.6	TOC, mg/l
to lime treatment	852	272
to carbon columns	252	177
from carbon columns	76	100
% removals from feed to lime treatment:		
in lime treatment	70	35
in carbon adsorption	21	28
total	91	63

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TABLE 6

REMOVAL OF COLOR AND TOC BY
FACET CARBON ADSORPTION FOLLOWING LIME TREATMENT FOR 12-DAY PERIOD
10/20 THROUGH 11/6 (29)

Conditions:

Water feed rate	10 gpm
Carbon feed rate	2.7 lb/hr = 4.5 lb/1000 gal
Carbon in system	605 lb
Carbon slurry density	14.3 g/100 ml slurry
Stages	3

Removals:	Color, C.U. APHA pH 7.6	TOC mg/l
Feed	157	158
Product	73	101
Percent removal	54	36
Removed, mg/g carbon	214	136
Removal rate, mg/g x hr	0.71	0.46

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TABLE 7

WASTE WATER RENOVATION--SUMMARY OF RESULTS (25)

Treatment Step		5-DAY BOD: Four-stage process mg/liter	5-DAY BOD: Four-stage process % Removal	5-DAY BOD: Three-stage process mg/liter	5-DAY BOD: Three-stage process % Removal	COLOR: Four-stage process Units	COLOR: Four-stage process % Removal	COLOR: Three-stage process Units	COLOR: Three-stage process % Removal
Raw	Max.	1430		265		12,000		5250	
	Min.	225		206		1,000		240	
	Avg.	723		221		5,200		3558	
Lime	Max.	740		144		1,000		450	
	Min.	170		69		90		10	
	Avg.	395	45.5	102	54	358	93	185	95
Biol.	Max.	135				1,000			
	Min.	21				200			
	Avg.	48	88			365	0		
Carbon	Max.	80		84		15		55	
	Min.	0		15		10		0	
	Avg.	23	53	32	68.5	13	96.5	23	87.5
Total		23	97	32	85.5	13	99.5	23	99.5

Tests Conducted on Bleached and Unbleached Kraft Effluents.

using the massive lime-biological-carbon system. Raw effluent color was 4800 and 3000 units respectively. This is shown in Tables 8 and 9.

McGlasson, et al. report that final color of 40 units was readily achievable by a biological oxidation -lime -carbon treatment system.

Operation Considerations

Timpe and Lang (29) concluded that the use of a sand filter ahead of the carbon system did not provide enough benefit to warrant consideration in a full-scale installation. They also noted concentrated bioactivity in the top one- or two-foot layer of the first column in series which caused plugging. Backwashing was required every one or two days. It was also noted that mechanisms other than adsorption contributed substantially to color removal. One mechanism has been referred to as a coagulation of the colloidal color bodies at the surface of the carbon particle. In the section on "System Efficiencies," it was explained that in Timpe's lime-carbon system, lime dosages were recommended to control the dissolved calcium concentration at about 80 ppm. A benefit of this, as reported, is the elimination of the necessity to carbonate the effluent to remove the calcium. Higher dosages could make carbonation required prior to reuse of the effluent. The lime treatment system also produced a sludge that dewatered readily to 70 percent solids. The authors also state that lime treatment to higher dissolved calcium levels of 400 mg/l, followed by carbonation and carbon treatment did not improve color reductions.

Timpe and Lang are enthusiastic about the possibilities of the FACET system. They state that the rate of TOC removal was 4.7 times the rate of removal in columns. Also, the degree of color removal was the same as in the columns, but with one-fifth the amount of carbon. More work is planned.

The work performed by Timpe has been directed towards reuse of the treated effluent. As such, the degree of treatment obtained is less than typical discharge standards. At this time, the effect of recycled effluent on mill processes has not been tested. Timpe and Lang are confident the kraft process contains unit processes by which any buildup in contaminants due to recycling can be purged from the system (30).

Smith and Berger (25) found that elimination of biological oxidation in the lime - carbonation - biological - carbon sequence did not affect color reduction and BOD reduction remained about 85 percent when treating effluents with a moderate raw BOD. They point towards further research toward improved BOD reduction in the lime stage and use of more effective carbons. They also look to requirements for advanced treatments leading to recycle of waste waters and see the possible elimination of biological systems as recycle becomes more important.

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TABLE 8

RENOVATED WATER ANALYSIS (26)

UNBLEACHED KRAFT LINERBOARD TOTAL MILL EFFLUENT
PILOT PLANT RUN NO. 1 50 GALLON BATCH OPERATION ( )

Constituent	Desired Range	Effluent	Obtained by Treatment: Lime[a]	Bio[b]	Carbon[c]
Turbidity, ppm	5-25	-	-	65	10
Color, units	0-80	4800	140	200	10
pH	6.5-7.7	8.7	11.5	9.1	8.7
Hardness, ppm $CaCO_3$	5-200	107	7.1	86	61
Dissolved solids, ppm	50-500	3380	2510	2650	2500
Chloride, ppm	10-150	110	140	36	36
COD, ppm	0-12	-	-	201	1
BOD, ppm	0-5	818	460	8	2
Na, ppm	-	1400	1130	1600(d)	1400

Notes: (a) 8.40 lbs, reburned lime slaked and added to raw effluent (equivalent to 20,000 ppm $Ca(OH)_2$).

(b) Extended aeration for 10 days. One gallon fertile lake water added as seed material. NH_4OH, HNO_3 and H_3PO_4 added as nutrient. H_2SO_4 added to neutralize.

(c) Carbon columns containing 12x40 mesh activated carbon furnished by Pittsburgh Carbon. Contact time in the carbon bed was 8.2 minutes.

(d) Possible NH_4^+ interference.

TABLE 9

RENOVATED WATER ANALYSIS (26)

UNBLEACHED KRAFT LINERBOARD TOTAL MILL EFFLUENT
PILOT PLANT RUN NO. 2 50 GALLON BATCH OPERATION

Constituent	Desired Range	Effluent	Obtained by Treatment		
			Lime[(a)]	Bio[(b)]	Carbon[(c)]
Turbidity, ppm	5-25	-	-	-	-
Color, units	0-80	3000	100	200	15
pH	6.5-7.7	7.5	12.1	8.2	8.5
Hardness, ppm $CaCO_3$	5-200	-	964	1000	866
Dissolved Solids, ppm	50-500	4190	2610	3070	2800
Chloride, ppm	10-150	160	200	130	130
COD, ppm	0-12	-	-	-	-
BOD, ppm	0-5	1430	740	(135)[(d)]	(80)[(d)]
Na, ppm	-	320	230	230	230

Notes: (a) 2.87 lbs. reburned lime slaked and added to raw effluent (equivalent to 7500 ppm $Ca(OH)_2$).

(b) Extended aeration for 8 days. One gallon fertile lake water added as seed material. HNO_3, H_3PO_4 added as nutrient. H_2SO_4 added to neutralize.

(c) Carbon columns containing 12x40 mesh activated carbon furnished by Pittsburgh Carbon. Contact time in carbon bed was 1.6 minutes.

(d) Estimate, incubator problems.

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ADVANCED WASTE TREATMENT (AWT)

Introduction

In order to establish reasonable effluent guidelines, the current and future status of various Advanced Waste Treatment systems, and the applicability to the subcategories of the pulp and paper industry must be evaluated. Specifically, areas of concern are:

1. Removal of turbidity and colloidal and suspended solids
2. Removal of dissolved salts and dissolved solids
3. Removal of refractory organics
4. Removal of nutrients

High rate filtration, either sand or mixed media, has been used for effluent polishing in the domestic field, but to date has not been used in the pulp and paper industry subcategories under study for effluent treatment. Reverse osmosis has been extensively investigated for possible application within the pulp and paper industry. All of the work, however, has been undertaken on a pilot plant basis. The progress made with reverse osmosis systems within the past five years suggests that it could in the future be a very valuable tool in waste treatment for removal of color and suspended and total dissolved solids. At present this method seems particularly applicable to NSSC mills. While many of the mechanical problems have been solved, membrane life and flux rates have not progressed to the extent where large scale applications can be considered. If membrane life can be improved and flux rates increased, then the total costs could be lowered.

The AWT system which has been evaluated for the removal of dissolved salts and dissolved solids incorporates unit operations of reverse osmosis and ion exchange. In addition, specific methods for the removal of phosphorus and nitrogen compounds have been considered.

Ion exchange has been extensively employed for treating water, but its application to waste treatment has been negligible. Research and pilot plant projects have been undertaken to determine its efficiency for removing dissolved salts and dissolved solids from waste streams. Depending on the type of ion exchange process, regenerate disposal could be a problem. In addition to the removal of total dissolved solids and dissolved salts, specific ion exchange processes for the removal of nitrogen and phosphorus compounds have been employed in several domestic facilities but not in the treatment of pulp and paper waste flows, primarily because only the ammonia NSSC base mills are high in nitrogen.

The AWT systems which have been considered for the removal of trace refractory organics are activated carbon, chlorination, and ozonation. The activated carbon process has demonstrated its applicability to the treatment of municipal wastes at full plant scale while pilot and laboratory studies have shown the potential of its use in the treatment of pulp and paper mill wastes. The potential of chlorination and ozonation, however, is not well documented. While there has been limited investigations concerning the general use of chlorination or ozonation for the removal of trace refractory organics, there are no plant scale operations.

Turbidity and Colloidal and Suspended Solids

The primary advanced waste treatment systems for the removal of turbidity and colloidal and suspended solids are: 1) sedimentation, coagulation, and flocculation followed by settling; 2) filtration; and 3) reverse osmosis. The majority of the work undertaken for coagulation and flocculation of pulp and paper mill wastes has been undertaken in conjunction with color removal.

Filtration, either sand or multi-media, is a commonly used process in the advanced waste treatment of domestic waste waters for removal of suspended solids. Its use, however, for the removal of turbidity and colloidal and suspended solids from mill effluents is not documented in the literature.

The reverse osmosis (hyperfiltration) process has received considerable attention within the pulp and paper industry during the past several years as a possible economic means of sufficiently treating the spent pulping process waters for major internal reuse. The initial work with membranes was in conjunction with an electrodialysis system (31). Electrodialysis investigations of pulp liquors provided important background on new membrane processes such as ultrafiltration and reverse osmosis. The application of reverse osmosis membranes has been centered on concentrations of dilute streams in the range of one-half to one percent suspended solids (32)(33).

The Pulp Manufacturers Research League and The Institute of Paper Chemistry have investigated the reverse osmosis process for treatment of pulp and paper mill waste waters under a project partially sponsored by the Office of Research and Monitoring of the Environmental Protection Agency (33). Their studies led to confirming trials conducted in field demonstrations ranging from 18,900 to 189,300 liters per day (5000 to 50,000 gallons per day) on five different waste flows. The five field demonstrations were undertaken on:

1. Ca Base Pulp Washing and Cooling Waters
2. NSSC White Water
3. NH_3 Base Pulp Wash Water (also Calcium Hypochlorite Bleach Effluent)
4. Kraft Bleach Effluent (also Kraft Rewash Water)
5. Chemimechanical Pulping Wash Water

Their study concluded that the reverse osmosis process is an important new tool for concentrating and recovering solutes in dilute pulp and papermaking effluents (33). They obtained membrane rejections of 90 to 99 percent for most components in the feed with the exception of low molecular weight salts and volatiles which were less well rejected.

One mill has also undertaken detailed studies for the use of reverse osmosis as a unit operation for producing water suitable for process reuse under a program also partially funded by the office of Research and Monitoring of the Environmental Protection Agency (32). This study included the operation of proprietary reverse osmosis equipment on a pilot basis by vendors simultaneously and continuously on the same feed. This allowed the development of operating techniques applicable to the particular feed and development of design criteria for the design of a full scale production facility. This study also concluded that the reverse osmosis process is effective in concentrating the dilute waste stream while producing a clarified water flow that can be recycled for process purposes (32). The concentrated stream would be directed to the fluidized bed reactor operating as part of their chemical recovery system. Three basic types of reverse osmosis membrane surfaces are available:

1. Capillary fiber
2. Sheet membrane (spiral round)
3. Tubular

Tubular membranes have been found to be the most suitable in the work that has been undertaken because capillary fiber and sheet membranes were more subject to clogging problems (33). Most of the work with reverse osmosis has been concerned with the use of cellulose acetate membranes, but some work with dynamic membranes, or replaceable membranes, is receiving more attention as it could substantially reduce the cost of reverse osmosis systems (31)(34).

It is stated by Beder, et al.that the reverse osmosis process would best fit into a treatment scheme following primary treatment, prior to activated carbon polishing if the benefits derived from the improved solids removal and the elimination of pretreatment with massive lime and large scale activated carbon are greater than the incurred loss of membrane capacity resulting from lower flux rates (35). While hyperfiltration is very effective in removing color and macromolecular organic compounds, certain lower weight molecular organic compounds are not rejected by the reverse osmosis process and activated carbon polishing would be required, for certain uses.

Johnson, et al. state that if color removal only is necessary, the ultrafiltration which is not as effective as hyperfiltration in removal of organic matters and solids, but is very effective in color removal, would be satisfactory (34).

The efficiency of the reverse osmosis process for several pulp and papermaking waste waters are presented in Table 10 (33).

TABLE 10

SUMMARY OF RESULTS OF TREATMENT BY REVERSE OSMOSIS (33)

WASTE FLOW	REPORTED REJECTION - %					
	TOTAL SOLIDS	BOD	COD	BASE	COLOR	WATER RECOVERY
Calcium Sulfite	87-98	69-89	87-95	95-99Ca	99	80-90
NSSC	96-98	87-95	96-98	82-95Na	99+	72-92
Ammonium Sulfite	93-96	77-94	92-97	92-98NH_3	99	65
Kraft Bleach	91-99	85-97	97-99	83-95Na	99+	---

The waste flows had to be pretreated by passage through a 40 mesh screen and the temperature adjusted to a safe operating range to protect the cellulose acetate membranes (below 40°C) (33).

The extensive pilot testing undertaken by a sodium base NSSC mill showed general rejections by the reverse osmosis process as follows (32):

Total Solids	-	99.7%+
BOD_5	-	98.6%+
Color-Optical Comparator	-	99.6%+
Na	-	99.5%+
Color-Spectrophotometer	-	99.8%+

The mixed media polishing filters can be used with or without addition of chemicals. This polishing filter is necessary when high quality water is required, but if the water is to be used for discharge to a natural stream, the use of such a filter is probably not justifiable (36).

The work by the Institute of Paper Chemistry indicated that fouling of reverse osmosis membranes by suspended particles, colloidal suspensoids of large molecular weight organics, etc., could be partially controlled by pretreatment, by periodic pressure pulsations, and by periodic washing of the membrane surfaces (33). Self-cleaning, high velocities of flow were found to be the most likely means of maintaining high flux rates through the membrane, especially with the newer high performance, tight surface membranes that became available in 1971. It was reported that minimum velocities of 0.61 meters per second (2 feet per second) overcame concentrative polarization, but 0.91 meters per second (3.0 feet per second) were required to maintain adequate mass transfer rates (32). It was also stated that concentration polarization did not appear to seriously affect performance at operating pressures below 55.4 atm. (800 psig).

Present commercial hyperfiltration membranes cannot be operated at temperatures much above ambient and cooling of many pulping effluents is therefore necessary. Dynamically formed membranes, however, have been shown to suffer less from these disadvantages and may be preferrable when a high degree of salt removal is not required (34). In addition, ultrafiltration membranes are more open than the tighter reverse osmosis (hyperfiltration) membranes and while rejection for colored ligonsulfonates are high, other components are rejected to a much less satisfactory degree. Research is being carried out to develop improved rejection with ultrafiltration membranes because it has higher flux rates than hyperfiltration and the advantages of simplified equipment design (31). In addition, a major roadblock delaying the practical use of reverse osmosis in waste treatment lies in the several causes of short life expectancy in the membrane system. Membrane manufacturers should be encouraged to obtain goals of a minimum three-year life expectancy for these membranes (33). In addition, membrane development should include a capability for operating at wider ranges of pH and temperature (33) and higher flux rates.

Dynamic membrane studies should be advanced to achieve higher levels of solid rejection without serious reduction in permeate rates and flux rates. The development of these membranes could substantially improve performance and cost parameters (34)(39)(36).

Dissolved Salts and Dissolved Solids

Processes which can be used for the purposes of removing dissolved salts and dissolved solids from pulp and papermaking waste flows are of primary concern. In work undertaken by Beder and Gillespie (35), it is stated that process water for bleached and unbleached kraft production should contain less than 500 and 250 mg/l of total dissolved solids, respectively. In addition, chlorides, because of their corrosive nature should be less than 150 mg/l. The ultimate goal of the current federal water pollution control legislation will require that certain portions of the waste stream be treated to achieve the above TDS and chloride levels if substantial reuse is undertaken. The prime unit processes that could be employed to achieve high degrees of TDS and chloride removals are reverse osmosis and ion exchange.

Pilot work at a sodium base NSSC mill (38) showed average soluble solids rejections of 99+ percent, with product water soluble solids ranging from below 100 mg/l to about 760 mg/l depending on the percent of feed solids. Average rejection of sodium was 99+ percent, with product water sodium ranging from less than 20 mg/l to about 180 mg/l depending on the percent of feed solids.

Table 11 shows the total solids removals with reverse osmosis achieved in the work undertaken by the institute of Paper Chemistry (33).

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TABLE 11

TOTAL SOLIDS REMOVAL (34)
REVERSE OSMOSIS

Waste Flow	Feed g/l	% Rejection	Effluent Conc. Range g/l
Calcium Sulfite	18.47-11.05	87-98	2.04 - 0.37
NSSC	10.75-5.72	96-98	0.68 - 0.32
Ammonium Sulfite	10.31-50.48	94-97	6.44 - 0.66
Kraft Bleach	/		

The reported data from pilot and laboratory work indicated that reverse osmosis is very effective in removing TDS and chlorides from selected pulp and paper industry flows. The ultimate concentration of each element, however, will be dependent on the initial concentrations and the recovery and treatment processes preceding reverse osmosis.

Ion exchange has been a well-known method for softening and de-ionizing water, but application to wastewater treatment has been negligible primarily because high molecular weight organic compounds present in wastewater have a deleterious effect on most anion exchange materials and disposal of regenerates is a major problem. New types of resins have been developed, however, that are less affected by organics. As pointed out by the work undertaken by Kreusch and Schmidt (37) separation techniques using ion exchange demineralization are known, but their application to waste treatment is not generally practiced, nor is there sufficient information on such a system to predict performance.

As pointed out in the work undertaken by Timpe, et al.(9), the DESAL process is a de-ionization technique based upon two weak electrolyte ion exchange resins. The advantages of this process over conventional ion exchange process are claimed to be:

1. Ability to treat brackish waters at concentrations of 500 to 3000 ppm dissolved solids with negligible leakage.

2. Stoichiometric amount of regenerates required for regeneration versus conventional methods which require 200 to 300 percent of stoichiometric amount; therefore, regeneration costs are significantly less.

3. High degree of utilization of theoretical capacity.

The DESAL Process uses three beds of weak ion exchange resins in a cyclic process. The first bed is a weak base anion exchange resin; the second bed, a de-alkalization unit, is a weak acid cation exchange resin; while the third bed is in the free base form for carbonation. The alkalization and de-alkalization units can be regenerated with ammonia and sulfuric acid, respectively. At exhaustion, the third unit is in the bicarbonate form, so the direction of flow through the three units is reversed and the cycle repeated.

The work undertaken by Kreusch and Schmidt (37) involved ion exchange studies on sewage effluent from an activated sludge plant. The waste was pretreated prior to ion exchange with a system that consisted of lime clarification, dual media filtration, and granular activated carbon filtration to reduce the total phosphate, suspended solids, and total organic carbon of the wastewater prior to ion exchange. The investigations included the performance of the following resins:

1. Weak Base Anion Exchange - Bicarbonate Form

2. Strong Acid Cation Exchange - Hydrogen Form

3. Weak Base Anion Exchange - Free Base Form

4. Weak Acid Cation Exchange - Hydrogen Form

5. Weak Acid: Strong Acid Cation Exchange - Hydrogen Forms

Kreusch and Schmidt's (37) work concluded that the ion exchange process with the weak base anion exchange resin - bicarbonate form was not sufficiently established to use on domestic sewage containing less than 500 mg/l of dissolved solids. Their work did show, however, that a system using a strong acid cation exchange resin and a weak base anion exchange resin can be used without difficulty for a waste water containing as much as 500 mg/l of total dissolved solids. In addition, a weak acid cation exchange resin can be very efficient as the first resin to demineralize certain waste waters.

The work undertaken by Linstedt et al. (39) showed that a cation-anion exchange system was very effective in the removal of major ions from a domestic secondary effluent. The results of this work are shown in Table 12 (39).

Timpe et al. (9) state that ion exchange for the de-ionization of partially renovated waste waters is technically feasible for domestic and pulp and paper mill wastes. In order to successfully use ion exchange processes, the majority of organics and suspended solids must be removed from the waste stream. In the laboratory work undertaken by Gregory and Phond (40), the effluent from a well-operated domestic activated sludge plant was used without any additional treatment. In the work reported by Berger and Thibodeaux (26) which consisted of laboratory sized columns and equipment, the selected kraft mill waste stream was clarified and treated with lime and activated carbon prior to ion exchange, while the domestic waste used by Kreusch and Schmidt (37) was similarly treated.

If the waste streams are not properly pretreated prior to ion exchange, severe operational problems due to clogging will be encountered. With biological treatment, the waste stream probably would require a minimum of mixed media filtration for suspended solids removal as pretreatment. Depending on the organic nature of the secondary effluent, it may have to be pretreated with activated carbon, or reverse osmosis. If the total dissolved solids of the waste stream exceeds 3000 mg/l, pretreatment with reverse osmosis may be necessary to keep cost of ion exchange within reason.

Proper disposal of waste regenerates associated with the use of ion exchange treatment of waste waters must be fully recognized. Effective

TABLE 12 (39)

BEHAVIOR OF MAJOR CHEMICAL CONSTITUENTS IN RENOVATION SYSTEM

	Concentration or Value						
	Before Coagu-lation	After Settling	After Recar-bonation	After Sand	After Carbon Adsorption	After Cation Exchange	After Anion Exchange
Ca++ as $CaCO_3$ (mg/l)	62	205	62	-	-	0	-
Na+ (mg/l)	49	44	44	-	-	0.7	-
Cl^- (mg/l)	53	48	42	-	-	-	2.5
SO_4^- (mg/l)	145	130	127	-	-	-	0
Alkalinity as $CaCO_3$ (mg/l)	175	260	139	-	-	-	5.9
COD (mg/l)	131	102	-	61	16	12.5	10.8
Solids							
Total (mg/l)	431	377	336	254	233	68	24
Fixed (mg/l)	312	257	237	172	170	42	15
Volatile (%)	27.6	31.8	29.7	32.3	27.0	38.2	37.5
Turbidity (JTU)	16	1.5	2.3	4.1	0.23	0.25	0.23
pH	7.3	11.4	7.6	8.0	8.8	3.0	4.8

regeneration requires regenerate volumes in excess of stoichiometric quantities. Strong resins require large excesses while weak resins only require small excesses. In order to greatly reduce the regenerate volume to be treated, the ion exchange process should consider fractionation of the total effluent during regeneration and use ( ). Acid wastes are easily neutralized, but precipitated sludges and neutral brines must be satisfactorily disposed of. Waste regenerant ammonium hydroxide from the anion exchange resin can be treated with hydrated lime, with the liberated ammonia recovered and reused.

A summary of common pretreatment requirements prior to the ion exchange process is presented in Table 13 (41).

Trace Refractory Organics

The advanced waste treatment systems studied for the removal of trace refractory organics include the following: 1) activated carbon, 2) chlorination, and 3) ozonation. The activated carbon process has demonstrated its applicability to the treatment of municipal wastewater at full plant scale. Pilot plants and laboratory studies have shown the potential for treatment of pulp and paper mill wastes with activated carbon. However, the potential of the other processes is not well documented and there are no plant scale operations utilizing them. The removal of one specific refractory organic, color, is discussed in detail in a separate subsection.

Activated carbon has been used at water treatment plants to remove organics that caused taste and odor problems in drinking water supplies. The use of activated carbon as a step in the physical-chemical treatment process for domestic waste waters or as an add-on to an existing biological treatment system is well documented (37). Many researchers have studied the use of activated carbon as a tertiary process for the treatment of pulp and paper mill wastes (42)(43)(44)(45)(46)(29). Coates and McGlasson (46) found that activated carbon was capable of reducing color, COD, BOD, and odor in kraft mill effluents to very low concentrations.

One of the highest concentrations of BOD in the whole kraft pulp mill waste discharge is contained in the evaporator condensate (42). Most of the BOD and COD of the condensate waste is exerted by dissolved organic material. Hansen and Burgess (42) found that 75 percent of the BOD, COD, and TOD could be removed from the condensates by activated carbon adsorption.

Activated carbon is characterized by an extremely large surface area per unit weight (450-1800 sq. m/g) (29). This large surface area is one feature of activated carbon which results in its large adsorption capacity. It can be separated into two general classifications; powdered and granular. The ultimate adsorption capacities of both powdered and

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TABLE 13 (41)

PRETREATMENT REQUIREMENTS
FOR ION EXCHANGE

Constituent	Problem	Pretreatment Required
Suspended Solids	Blinds resin particles	Coagulation and filtration
Organics	Large molecules (e.g., humic acids) foul strong basic resins	Carbon adsorption or use of weak base resins only
Oxidants	Slowly oxidizes resins Functional groups become labile	Avoid prechlorination
Iron and Manganese	Coats resin particles	Aeration

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granular carbons are essentially equal (29); however, powdered carbon has faster adsorption rates than granular (46)(47). There are many carbon manufacturers with numerous specifications. The selection of a specific carbon cannot be made, however, without first testing the carbon under consideration with the particular effluent to be treated (48).

The activated carbon process has various configurations which include: use of granular or powdered carbon, contact in a column or slurry, fixed or moving beds, upflow or downflow of influent, series or parallel arrangement, and continuous or periodic wasting and regeneration of spent carbon. Treatability of a particular waste by activated carbon is described by various analytical adsorption isotherm equations which are covered in depth in the literature. The Freundlich equation is probably the most frequently used to determine adsorption isotherm. However, poor correlation between isotherm results and column tests have been reported. This is partially due to the fact that adsorption is not the only mechanism responsible for the removals of organics through carbon columns. Three functions describe the operation of carbon columns (49); adsorption, biological degradation, and filtration.

Most of the researchers studying activated carbon have made one common assumption -- i.e., that the effluent from the carbon system should be of a sufficient quality to permit reuse as process water. According to Smith and Berger (44), renovated waste water suitable for reuse can be obtained without a biological oxidation step, particularly if the renovation process starts with a moderate BOD_5 of 200-300 mg/l. Table 14 presents the pilot plant results obtained by Smith and Berger.

Weber and Morris (50) and others found that adsorption equilibrium increased with a decrease in pH. The effect on the rate of adsorption with changes in temperature is not well defined.

Activated carbon will not remove certain low molecular weight organic substances, particularly methanol, a common constituent of pulping effluents (45). Also, carbon columns do a relatively poor job of removing turbidity and associated organic matter (48). Some highly polar organic molecules such as carbohydrates will not be removed through carbon columns (48)(42). However, most of these materials are biodegradable and would not be present in appreciable quantities in a well bio-oxidized secondary effluent (48).

Results of laboratory rate studies, by Davies and Kaplan (47), using powdered activated carbon to treat municipal secondary effluents, showed that 90 percent of equilibrium adsorption capacity could be obtained in less than five minutes using turbulent mixing. Davies and Kaplan considered five different contact systems during their laboratory investigation. The systems considered were:

1. Countercurrent agitated tank adsorption

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TABLE 14 (44)

RESULTS OF GRANULAR ACTIVATED CARBON COLUMN
PILOT PLANT TREATING UNBLEACHED KRAFT MILL WASTE

	Columns* Preceded by Lime Precipitation and Biological Oxidation			Columns* Preceded by Lime Precipitation					
	Influent	Effluent	Removal	Influent	Effluent	Removal	Influent	Effluent	Removal
BOD, mg/l	48	23	52%	102	32	69%	82	12	85%
COD, mg/l	—	—	—	—	—	—	320	209	35%
SS, mg/l	—	—	—	—	—	—	115	74	36%
Turbidity, J.U.	—	—	—	—	—	—	35	35	0%
Color, Units	—	—	—	—	—	—	28	0	100%
Odor	365	13	96%	185	23	88%	—	—	—
pH	—	—	—	—	—	—	11.9	10.5	12%
T.S. mg/l	—	—	—	—	—	—	1285	1205	6%

*Columns loaded at 3.6 - 4.0 gpm/ft^2

2. Flotation adsorption

3. Diffusion adsorption

4. Packed bed columnar adsorption

5. Upflow column adsorption.

Based on their investigation, Davies and Kaplan considered the countercurrent agitated tank system the most promising of the five systems for the following reasons:

1. The secondary effluent did not have to be filtered prior to contact.

2. Variable secondary effluent flow rates and effluent COD concentrations could be readily handled.

3. Maintenance costs were low.

4. Design and operation was simple.

5. The system was truly continuous.

6. COD removals to approximately 5 mg/l could be achieved.

7. The potential existed for treating primary treatment plant effluent.

8. Both suspended solids and colloidal material were brought down with the carbon due to flocculation.

Davies and Kaplan reported that the processes investigated for separating the powdered carbon from the treated wastewater were not 100 percent effective and filtration of the wastewater was necessary to remove the carbon. In a full scale operation, the necessity to filter the effluent might make the use of powdered carbon economically impractical.

Tests by Hansen and Burgess (42) showed that 70-75 percent of the organic matter from kraft evaporator condensate could be removed with 0.46 kilograms of carbon per kiloliter (3.8 pounds of carbon per 1000 gallons) of waste water. It was also determined that an extended contact time (over 1 hour) showed insignificant additional COD removal. However, even after six hours of contact there was an effect on the removal of toxicity which was attributed to other various constituents. The results of the work by Hansen and Burgess conflict with that reported by Timpe and others. Other researchers have reported that activated carbon is not effective in removing low molecular weight organics such as methanol and other major constituents of evaporator condensates from the kraft pulping operation. The condensate used by Hansen and Burgess may have been contaminated with black liquor carry over.

Timpe and Lang (29) ran extensive pilot plant tests for treating unbleached kraft mill effluent with activated carbon. Their 114 liter per minute (30 gpm) pilot plant utilized four different treatment processes. They were as follows:

1. Clarification followed by downflow granular carbon columns.

2. Lime treatment and clarification followed by granular carbon columns.

3. Biological oxidation and clarification followed by granular carbon columns.

4. Lime treatment and clarification followed by FACET (Fine Activated Carbon Effluent Treatment). (Subject of a patent application.)

All treatment processes were operated in the attempt to obtain a treated effluent with less than 100 APHA color units and less than 100 mg/l TOC which would be suitable for reuse. The lime-carbon treatment achieved the desired effluent criteria and was considered the most economical of three processes utilizing carbon columns. A relatively small lime dosage of 320-600 mg/l CaO without carbonation prior to carbon treatment was reported to be the optimum operating condition for the lime-carbon process. It should be emphasized that the lack of carbonation was a criteria for optimum treatment. It was determined that the effluent should contain about 80 mg/l Ca for successful optimization of treatment. The required fresh carbon dosage was 0.30 kilograms of carbon per kiloliter (2.5 pounds of carbon per 1000 gallons) treated.

With biological oxidation and clarification followed by carbon columns, the fresh carbon dosage was 0.96 grams of carbon per liter (eight pounds of carbon per 1000 gallons) treated.

It was found that non-adsorptive mechanisms accounted for a significant amount of color and TOC removal in the clarification-carbon process. It was felt that the removals were not due to any biological degradation which might have occurred within the carbon columns. It was determined that the color in colloidal form coagulated on the carbon surface. The color colloids were subsequently removed as large settleable solids during the backwashing process (29). The method of disposal or recycle of the backwash water was not discussed. The disposal of backwash water is a major item and cannot be ignored on full scale designs.

The FACET system studied by Timpe and Lang is the subject of a patent application (29). It is a multi-stage, countercurrent, agitated system with a continuous transfer of both carbon and liquid. One of the major aspects of the FACET system is the use of an intermediate size carbon endeavoring to combine the advantages of both powdered and granular carbon while minimizing their limitations. Equipment size and carbon inventory are decreased due to the increased adsorption rate of the intermediate carbon. Timpe and Lang reported that the FACET system showed distinct advantages over the column adsorption system. Table 15 tabulates the pilot plant results obtained from Timpe and Lang's investigation.

The use of granular activated carbon for the removal of trace refractory organics is technically sound. However, when this degree of treatment is obtained, the ability to reuse the effluent for process water is desirable. Powdered activated carbon has not been widely utilized because of difficult handling problems encountered in carbon recovery and regeneration (47). Davies and Kaplan (47) reported that the control of pH or temperature, though advantageous to the operation of the process, would be economically impractical.

Beebe and Stevens (51) utilized a carbon slurry to treat municipal wastes. They reported a tendency of the compacted slurry in the quiescent concentrator to form a gelatinous mass. It became necessary to agitate the gel to reliquefy it for easy removal.

Davies and Kaplan (47) studied the use of powdered carbon columns. They found that the columns became clogged with colloidal matter within a few hours of operaton and pressure drops became prohibitive. They tried the upflow contact process, but the bed could not be stabilized and serious channeling occurred resulting in poor COD removal efficiencies. Polyelectrolyte flocculation was determined to be the most economical method to recover spent powdered carbon. It was also determined that a suspended solids concentration of 500 mg/l or more must be maintained in the carbon slurry to assure flocculation efficiency.

Bishop et al. (48) ran pilot plant tests on domestic secondary effluent and reported that organic matter which was adsorbed on the carbon went septic and produced a breakthrough of turbidity and organic matter. Timpe and Lang (29) reported similar results. They observed an H_2S odor in the treated effluent which indicated some biological activity within the first two feet of the carbon column which caused some plugging problems if the columns were not backwashed every day or two. They felt because of the low dissolved oxygen concentration that the biological activity was anaerobic. Chlorination of the influent to the carbon columns appears to eliminate sliming problems caused by biological activity within the columns.

Timpe and Lang (29) reported lower rates of adsorption, resulting in larger projected capital and operating costs, for the biological-carbon and primary-carbon processes for treating unbleached kraft mill effluent. The lower rates of adsorption were believed to be caused by coagulation

TABLE 15

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RESULTS OF ACTIVATED CARBON PILOT PLANTS TREATING UNBLEACHED KRAFT MILL EFFLUENT

Description Of Carbon Process	Columns Preceded By Biological Oxidation & Clarification			Columns Preceded By Primary Clarification			Columns Preceded By Primary Clarification			Columns Preceded By Lime Treatment & Clarification			FACET System		
	Inf.	Eff.	Removal	Inf.	Eff.	Removal	Inf.	Eff.	Removal	Inf.	Eff.	Removal	Inf.	Eff.	Removal
Hydraulic Load, gpm/ft^2	2.13			1.42			0.71			1.42			N.A.		
Carbon	Granular			Granular			Granular			Granular			Intermediate		
Contact Time, Min.	140									108					
BOD, mg/l										26% Removal					
TOC, mg/l	148	57	61%	220	83	62%	310	121	61%	177	100	44%	158	101	36%
Turbidity, J.U.											5-15				
Color, Units	740	212	71%	925	185	80%	1160	202	83%	252	76	70%	157	73*	54%
Fresh Carbon Dosage lb. carbon/ 1000 gal.	8			20.5			28			2.5			3.9		
pH										11.3					

*Filtered

of colloidal color bodies on the carbon surface. They also determined that the use of sand filters prior to the activated carbon was not necessary. The carbon columns operated with a suspended solids concentration of 200 mg/l without problems when backwashed every day or two. Filtration or coagulation of the effluent from the FACET process was necessary in order to remove that formed on the outer surfaces of the activated carbon granules.

Figure 9 (41) indicates the estimated cost per pound of COD removed for various influent and effluent COD concentrations and various design flows.

Chemical oxidation using chlorine or hypochlorite is an accepted means of disinfection for water supplies and wastewater effluents. Chlorination has also been found useful for the removal of ammonia nitrogen and odors from wastewater. However, the use of chlorination for the removal of trace refractory organics is not a well-documented process. Culp and Culp (52) report that the costs indicate that chlorine oxidation is not competitive with activated carbon adsorption for removal of relatively large quantities of COD from municipal wastes. It may offer an alternate for the removal of very small quantities of organics which have not been removed by activated carbon or as a temporary means of reducing the soluble BOD in the absence of adsorption equipment. No literature has been found that directs its attention specifically to the applicability of chlorination to the pulp and paper industry.

Holm (53) conducted a seven-month study of chlorination of approximately 303 million liters per day (80 mgd) of effluent from a conventional activated sludge process treating municipal wastewater. He determined that chlorination caused a substantial reduction in the BOD_5. The BOD decreased an average of 34.5 percent. Very good effluent or effluent from a bulking plant was not significantly improved. Effluent of 12 to 30 mg/l of BOD was noticeably improved. Holm also monitored the suspended solids, PO_4, and TOD. He found that the suspended solids concentration increased about 20 percent. He theorized that some of the soluble compounds were "precipitated" into a suspended state by the chlorine. The PO_4 and TOD were not significantly affected by chlorination. Meiners (54) studied chlorine oxidation, catalyzed with ultraviolet radiation, for the treatment of domestic wastewater. He found that chlorine will slowly oxidize only a small fraction of dissolved organic material in the dark, but in the presence of ultraviolet radiation, rapid elimination of large amounts of COD and TOC is possible.

The most important factor involved in the process was the selection of the source of radiant energy. Meiners determined that short-wavelength radiation (below 300 mu) is more effective than long-wavelength radiation in promoting the chlorine oxidation process. Radiation of 254 mu was about six times more effective than polychromatic radiation between 300-370 mu. He found that the rate of organic oxidation was increased by increased radiation intensity; however, lower intensities produce

FIGURE 9

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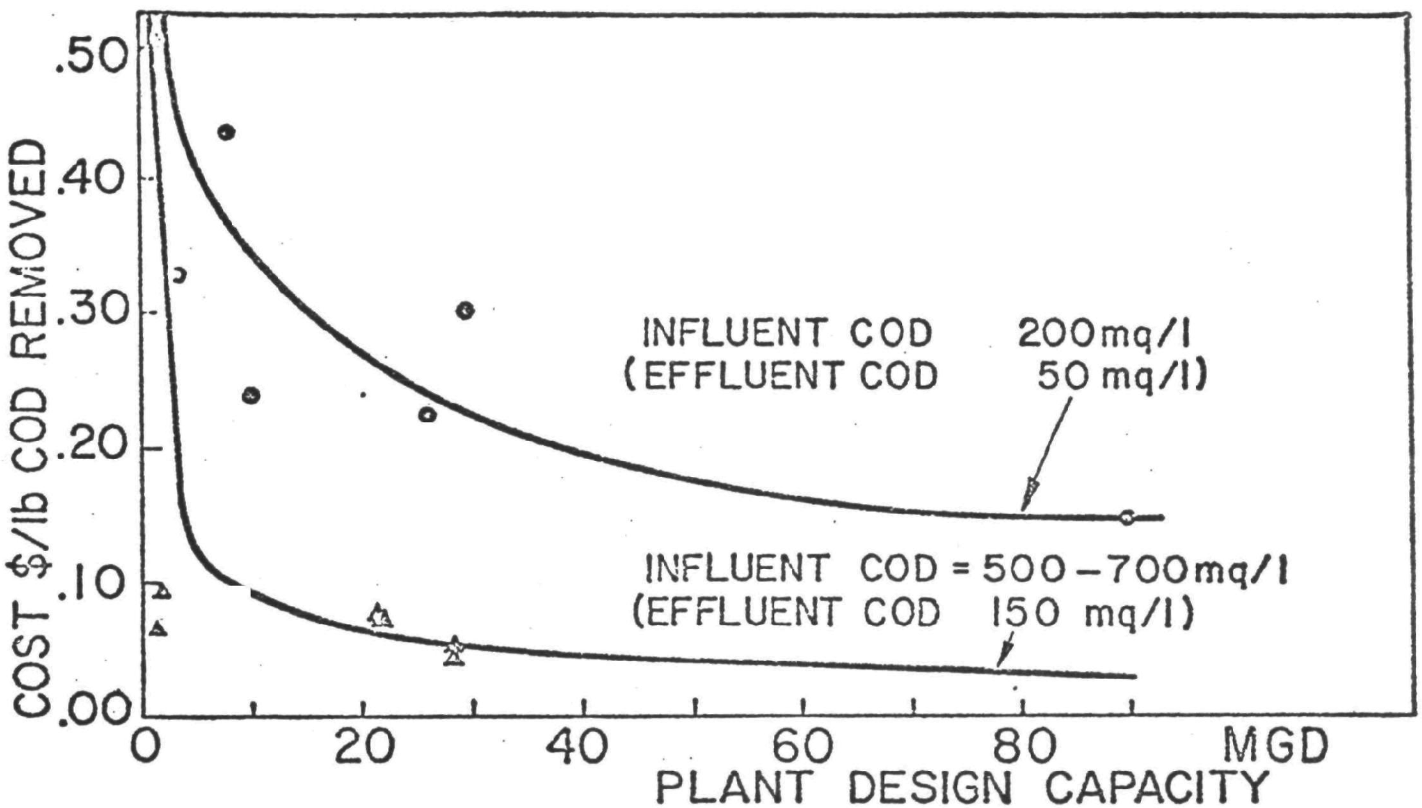
ECONOMY IN SCALE - CARBON ADSORPTION SYSTEMS



1. Costs based on ENR = 1400.

2. Unit costs assume an annual capital recovery factor of 0.0877.

3. Costs include initial carbon inventory, carbon handling system, and regeneration facilities.

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more overall organic oxidation for a specific amount of absorbed radiant energy than do higher intensities. It was also established that the chlorine consumption was directly proportional to the amount of radiant energy absorbed, regardless of intensity. The effectiveness of treatment is dependent on the penetration achieved by the ultraviolet radiation. However, the correlation of treatment efficiencies with influent color and turbidity concentrations was not reported.

Quantum efficiency is the amount of organic oxidation obtained from a given amount of absorbed radiant energy. Meiners observed higher quantum efficiencies at low intensities and an increase in quantum efficiency as the oxidation proceeded.

Meiners determined that mercury-arc lamps were the most practical source of radiant energy. However, the ideal mercury-arc lamp is presently not commercially available. Of those presently available, the low pressure mercury-arc is probably the most practical.

The most rapid rate of oxidation and the most efficient use of chlorine was obtained at pH 5. However, the most economic operation may be at ambient pH values without the addition of caustic for pH control.

Meiners also determined that chlorine concentrations above 5 mg/l produced no significant increase in the oxidation rate. High concentrations of chlorine were wasteful of chlorine and wasteful of radiant energy. It was concluded that an optimum chlorine concentration below 5 mg/l might be established where oxidation rates could be maximized and chlorine consumption minimized.

Ozone has been used for a number of years at water treatment plants as a deodorant and disinfectant. It has recently been utilized at municipal wastewater treatment plants to deodorize gases which are emitted and to disinfect the effluent. Ozone is a very effective disinfectant and oxidizing agent. It is about thirteen times more soluble in water than oxygen (55). Huibers et al. (55) have determined that ozone effectively reduces the COD and TOC content of effluents from municipal wastewater treatment plants, as well as odors, color, and pathogenic organisms.

Residual ozone decomposes very rapidly. It has a half-life in drinking water of about 20 minutes (55). Because of the instability of ozone, it must be produced at its point of use. The most common methods of producing ozone are (55):

1. Silent electric discharge in air or oxygen
2. Photochemical conversion of air or oxygen
3. Electrolysis of sulfuric acid

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Photochemical conversion is used only where small quantities in very low concentrations are required. Silent electric discharge is the only practical and economical method for large-scale production of ozone. In general, for large ozone usage, use of oxygen with recycle is a more economical system than using air (55).

Because of the expense involved, the use of ozonation to oxidize organics has not in the past been considered a practical form of tertiary treatment. Huibers et al. (55) have studied the use of ozone as a tertiary treatment process for domestic secondary wastewater effluent. However, no investigation of its applicability to the pulp and paper industry has been found.

Huibers et al. (55) conducted laboratory scale tests, about 37.85 liters per hour (10 gallons per hour), on the use of ozone to oxidize organics remaining in effluent from municipal secondary wastewater treatment plants. Effluent from a treatment plant using trickling filters was treated with ozone and virtually all the color, odor, and turbidity were removed. No living organisms remained, and the COD was below 15 mg/l. Ozone concentrations from 11 mg/l to 48 mg/l as oxygen proved equally effective.

Rates of COD and TOC removal were very dependent on agitation rates. Removals were increased approximately twofold using high-shear contacting rather than low-shear countercurrent contacting. Cocurrent contacting, mixing effluent and ozone in an injector, proved more desirable than the use of a turbine agitator. For effective ozonation, good agitation must be considered the prime objective in contractor design (55).

Low pH resulted in lower reaction rates, but higher ozone utilization efficiencies.

Ozone oxidizes many compounds which resist biological oxidation. However, the most readily bio-oxidizable organics also consume ozone the most efficiently (55). Chemical clarification prior to ozonation will remove a portion of the TOC that is resistant to oxidation by ozone resulting in lower final TOC level and less ozone consumption. Ozonation efficiency was high when COD and TOC concentrations were high. However, the effluent had an unacceptably high COD and TOC content. Huibers et al. concluded that effluents having high organic content (COD above 40 mg/l) are more economically treated by a combination of chemical clarification and ozonation. Effluents with a low organic content require only ozonation.

Because of the short life of ozone and the slow reaction of ozone with many organics, it was concluded that the best treatment would be achieved with multi-stage, high-shear, gas-liquid contacting. The half-life of ozone is approximately twenty minutes. From this, they determined that a residence time of ten minutes per stage was reasonable. One hour was

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needed for a COD reduction from 35-40 mg/l to 15 mg/l. Therefore, six stages were necessary. With the required amount of ozone being added to each stage as it was needed, an overall ozone efficiency as high as 90 percent was obtained.

Chen and Smith (56) reported that ozonation, catalyzed with activated Raney-Nickel removed 85 percent of the COD and 60 percent of the TOC from secondary treatment effluents in two hours under favorable conditions.

Huibers et al. (55) concluded that tertiary treatment with ozone has potential of an automated, trouble-free operation with low maintenance. Initially, they thought that the ammonia in the waste would react with the ozone but found that this was not the case.

The reduction of TOC is caused by organic molecules decomposing and giving off carbon dioxide (55). This rate of decomposition was reduced only at a pH below 7. A lower pH resulted in lower rates of COD removal because the activity of dissolved ozone was enhanced by higher pH. Lime dosage resulted in high pH, while alum-acid coagulants gave the lowest pH. A pH from 6.0 to 7.0 seemed to be optimum for multistage, cocurrent ozonation.

MONITORING

A necessary element of effective implementation of a program on effluent limitations guidelines and standards of performance is proper monitoring of effluent waste characteristcs by individual mills. The following procedures are recommended.

Flow Measurement

A properly designed, installed, and operated flow sensing device should be utilized to measure the entire flow at each point source. Such device should be capable of measuring flow over the entire flow range encountered. The sensing device should be recalibrated at least once each calendar quarter. More frequent recalibrations may be required if necessary to assure the required accuracy. Detailed records of all recalibrations should be maintained.

Each flow sensing device should be equipped with a flow integrator capable of totalizing flow over the required composite period, and over the entire flow range. Accuracy of the flow sensing-totalizing train should be at least within the limits of accuracy of best practicable equipment currently available, which normally will not exceed $\pm$6 percent of actual flow. Each such device should be equipped with an accurate means of indicating instantaneous flow rate, and should be located near the flow sensing device. A flow recording device capable of recording flow rate over a 24-hour period should also be provided for each flow sensing device.

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Each such device must be kept as clean as possible, and protected insofar as feasible from the weather and from all factors which may adversely affect its operation, maintenance, or accuracy.

Sampling

An automatic compositing sampler should be installed at or near each flow sensing device to take a periodic or continuous and representative sample of the flow passing through the flow sensing device at the time the sample is taken. The sampling interval should not exceed five minutes at normal average flow rate. Each liquid withdrawal should be a quantity whose volume bears a constant relationship to the flow rate at the time the withdrawal is made. Each such withdrawal should be deposited in a light-free compositing container which is maintained at the temperature prescribed by "Standard Methods for the Examination of Water and Wastewater" (57). All materials in contact with the sample should be corrosion-resistant, non-contaminating to the pollutant analyses described below, and easily cleanable. All surfaces of the sampling train exposed to the sample must be kept as clean as is reasonably possible and all reasonable precautions should be utilized to maintain the sampler in correct and continuous operation.

The composite sample (or a representative alliquot of the composite) should be removed at least every 24 ± 2 hours for analysis, on operating as well as non-operating days. The flow integrator reading should be recorded at this time. Persons handling samples shall be trained and competent in such procedures.

Analysis

Each composite sample (or alliquot) should be analyzed as prescribed by "Standard Methods for the Examination of Water and Wastewater" for the following constituents:

1. BOD_5;
2. Suspended solids;
3. pH;
4. Total phosphorus;
5. Total kjeldahl nitrogen;
6. The sum of nitrite nitrogen plus nitrate nitrogen.

All analyses should be conducted by trained and competent personnel.

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Records and Reporting

The following detailed records should be maintained and kept available for inspection for at least three years:

1. Flow meter calibration, recalibration, and malfunction records;

2. Sampler maintenance and malfunction records;

3. Analytical methods used, bench records, results, data, and summaries;

4. Production tonnage data, how and where measured, and conversion calculations to moisture-free basis.

Reports should be submitted to the appropriate agency by certified mail on a monthly basis.

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SECTION VIII

COST, ENERGY, NON-WATER QUALITY ASPECTS, AND IMPLEMENTATION REQUIREMENTS

COSTS

Actual treatment costs vary to a significant degree from mill to mill, depending upon the design and operation of production facilities and other local conditions. Effluent treatment costs which have been reported by the industry itself demonstrate this variance. The projected costs of achieving the effluent limitations which are proposed herein have been developed for a typical mill size in the subcategory under study.

Frequently there is more than one combination of unit processes available to achieve the proposed effluent limitation guidelines. Where this is the case the more expensive combination has been considered from a cost standpoint.

Costs of effluent treatment which are presented have considered the following:

Investment Cost

- Design
- Land
- Mechanical and electrical equipment
- Instrumentation
- Site preparation
- Plant sewers
- Construction work
- Installation
- Testing

Annual Cost

- Interest
- Depreciation
- Operation and maintenance

Operation and maintenance costs include labor, parts, chemicals, insurance, taxes, solid waste disposal, quality control, monitoring, and administration. Cost of energy is broken out as a separate item. Productivity increases or byproduct revenues as a result of improved effluent control are subtracted so that the operation and maintenance

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costs reported are the net costs.

Table 16 illustrates the costs for the recommended treatment and control technologies for the subject subcategory. Each cost shown reflects the total amount necessary to upgrade a mill which has only minimal internal control of spills, minimal recycling and recovery, and no treatment of waste waters to the specified technology level. It should be recognized that most mills have some existing capability beyond this base line, thus resulting in reduced costs over those shown.

TABLE 16

TREATMENT COSTS, $000
100 Short Ton Per Day Mill

Type of Cost	Technology Level I	II	III*
Total Investment Cost	915	1,463	624
Total Annual Cost	235	315	141
Depreciation and Interest	126	202	85
Operation and Maintenance	66	68	34
Energy	43	45	22

* Costs for Level III treatment and control technology do not include expenditures necessary for internal mill improvements. Sufficient data was not available to establish this portion of the costs.

All costs are expressed in terms of August 1971 prices. This is comparable to the following cost indices:

Index	Index @ August 1971
EPA Treatment Plant Construction Cost Index (1957-59 = 100)	164.5
EPA Sewer Line Construction Cost Index (1957-59 = 100)	166.8
ENR*Construction Cost Index (1913 = 100)	1614
ENR Labor Cost Index (1949 = 100)	420

*Engineering News Record

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ENERGY REQUIREMENTS

Specific energy and power prices shown in Table 16 above were based on the following and are reported as annual expenditures.

External treatment

power cost = 1.1¢/KWH
fuel price = $0.24/mill Kg Cal ($0.95/mill BTU)

Internal treatment

steam = $1.86/metric ton ($2.05/short ton)
power = 0.6¢/KWH

The lower power unit price used for internal treatment takes into consideration the lower cost of power generated by the mill, while power from external sources is assumed for external treatment.

NON-WATER QULAITY ASPECTS OF CONTROL AND TREATMENT TECHNOLOGIES

Air Pollution Potential

There is virtually no potential for an air pollution problem arising from the external treatment of effluents from building paper mills, although such problems are encountered in sludge disposal.

The physical processes employed in suspended solids removal do not involve any activity which would create air pollution, since detention times rarely exceed six hours which is not conducive to development of anaerobic or other odors. The subsequent biological processes are aerobic in nature when properly designed and operated, and the products of decomposition consist almost entirely of carbon dioxide, water, sulfates, and a trace of nitrates, all of which are odorless. The absence of objectionable odor has been confirmed by innumerable field observations by contractor personnel and regulatory officials. The only odors detectable were the characteristic odor associated with fresh natural water bodies and a faint aromatic odor of wood extractants. These are similar both in terms of character and intensity to those present in nature.

Odors can arise from land disposal of liquid sludges as a result of their anaerobic decomposition. These derive primarily from organic acids and hydrogen sulfide produced on reduction of sulfates dissolved in the water content of the sludges. Dewatering prior to disposal on the land arrests such decomposition and represents an adequate odor control measure, as do land fill practices.

Incineration of sludges produced in the effluent treatment processes can, without appropriate control equipment, result in the discharge of particulates to the atmosphere. However, emission control devices are available to meet state regulatory requirements in most instances. Incinerators are either sold with integral emission control appliances or are equipped with them on installation. Gaseous pollutant emissions from such incinerators are negligible.

In-mill controls which effect a reduction in fiber and additive losses such as save-alls and recycling of process waters do not generate an air pollution problem.

Noise Potential

There are no official records of public noise problems arising from the operation of effluent treatment by building paper mills. However, based on many years of contractor association with industry operations, it can be stated that public complaints engendered by such noise are very infrequent. This is due in part to their confinement, in some instances, to manufacturing or utility areas and to the fact that the noise level of most of the devices employed for treatment are generally lower than that of some manufacturing machinery.

The sources of noise are for the most part air compressors or mechanical surface aerators supplying air to treatment processes, vacuum pumps and centrifuges involved in sludge dewatering, and fans serving sludge incinerators. With the exception of surface aerators, these devices are most frequently operated in buildings which serve to muffle their noise.

Since many building paper mills are located in populated areas, noise from surface aerators could be a problem. However, these mills are small and employ small aerators which, if not driven through gear boxes, produce little noise. The problem of noise emanating from gear boxes used in these aerators and elsewhere is the subject of an extensive investigation by the Philadelphia Gear Company which manufactures many of these units. It is anticipated that this study will lead to a reduction in noise from these sources.

It can be concluded that noise produced by equipment used for treating building paper mill effluent is not a major public problem at present. Effort being made to reduce the noise level of mechanical equipment in general, motivated by industrial health protection programs, will lend assistance in preventing it from becoming one.

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Solid Wastes and Their Disposal

Solid wastes generated by building paper mills, in addition to sludges produced by effluent treatment, are trash, waste paper, ash, and garbage.

Trash such as metals, glass, and plastics is removed from waste paper and used rags in the beaters and/or pulpers and in stock cleaning operations. This material and grit from the rifflers are disposed of by land fill on the mill premises or hauled to a suitable location for disposal in this manner.

Wood rejects occur only in small quantities since less than 50 tons of wood a day is generally processed. In most instances, the rejects can be recycled in the process.

Ash from coal-fired boilers can be discharged hydraulically to ash ponds. There the solids settle and compact and the clear supernatant water is discharged to the mill effluent system. If ash is hauled to a disposal area, these materials should be transported wet in order to avoid being blown into the atmosphere.

Waste paper and garbage are either incinerated on the site or hauled away for disposal by contractors engaged in this business. Particulates from incineration must be controlled by effective devices such as bag filters or wet scrubbers.

Research has recently been conducted on solid wastes generated in the pulp and paper industry and their disposal for EPA's Office of Solid Waste Management Programs (EPA Contract No. 68-03-0207).

IMPLEMENTATION REQUIREMENTS

Availability of Equipment

Since 1966, when major federal water pollution control expenditures began, various federal and private organizations have analysed the projected levels of water pollution control activity and their economic impact on the construction and equipment industries. As a result, a plethora of studies has been developed which is related to the levels of municipal and industrial water pollution control construction and the respective markets for waste water treatment equipment. Less information is available concerning the actual and anticipated levels of expenditure by any specific industry.

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In recent years, the trend in the waste water equipment industry has seen the larger firms acquiring smaller companies in order to broaden their market coverage.

Figure 10 shows graphically past expenditures and projected future outlays for the construction of industrial waste water treatment facilities, as well as total water pollution control expenditures. Obviously, the level of expenditures by industry is related to the federal compliance schedule. This will increase until industry is in compliance with federal standards. Once that occurs, the level of spending will return to a level commensurate with the construction of new facilities, replacement of existing facilities, and the construction of advance waste treatment facilities.

Figure 11 shows past expenditures for and projected future trends in total sales of waste water treatment equipment and the dollar amounts attributable to industrial and municipal sales. This curve closely follows the trend shown in Figure

The data in Figures 10 and 11 related to industrial water pollution expenditures include only those costs external to the industrial activity. Internal process changes made to accomplish water pollution control are not included.

Recent market studies have projected the total available production capacity for water and waste water treatment equipment. Most of them have indicated that the level of sales is currently only 30-40 percent of the total available plant capacity. Several major manufacturers were contacted to verify these figures and indications are that they are still accurate. A partial reason for this overcapacity is that the demand for equipment has been lower than anticipated. Production capacity was increased assuming federal expenditures in accord with funds authorized by Congress and conformance to compliance schedules.

For the immediate future, increased demands for waste water treatment equipment can be absorbed by the existing overcapacity. Long term requirements will probably necessitate expansion of production capacity in various product lines where the demand is expected to increase dramatically -- specifically, advanced treatment systems and waste solids handling equipment.

It should also be noted that the capacity to produce waste water treatment equipment could be expanded significantly through the use of independent metal fabricators as subcontractors. Even at the present time independent fabricators are used by some equipment manufacturers when work loads are heavy and excessive shipping costs make it desirable to use a fabricator close to the delivery site.

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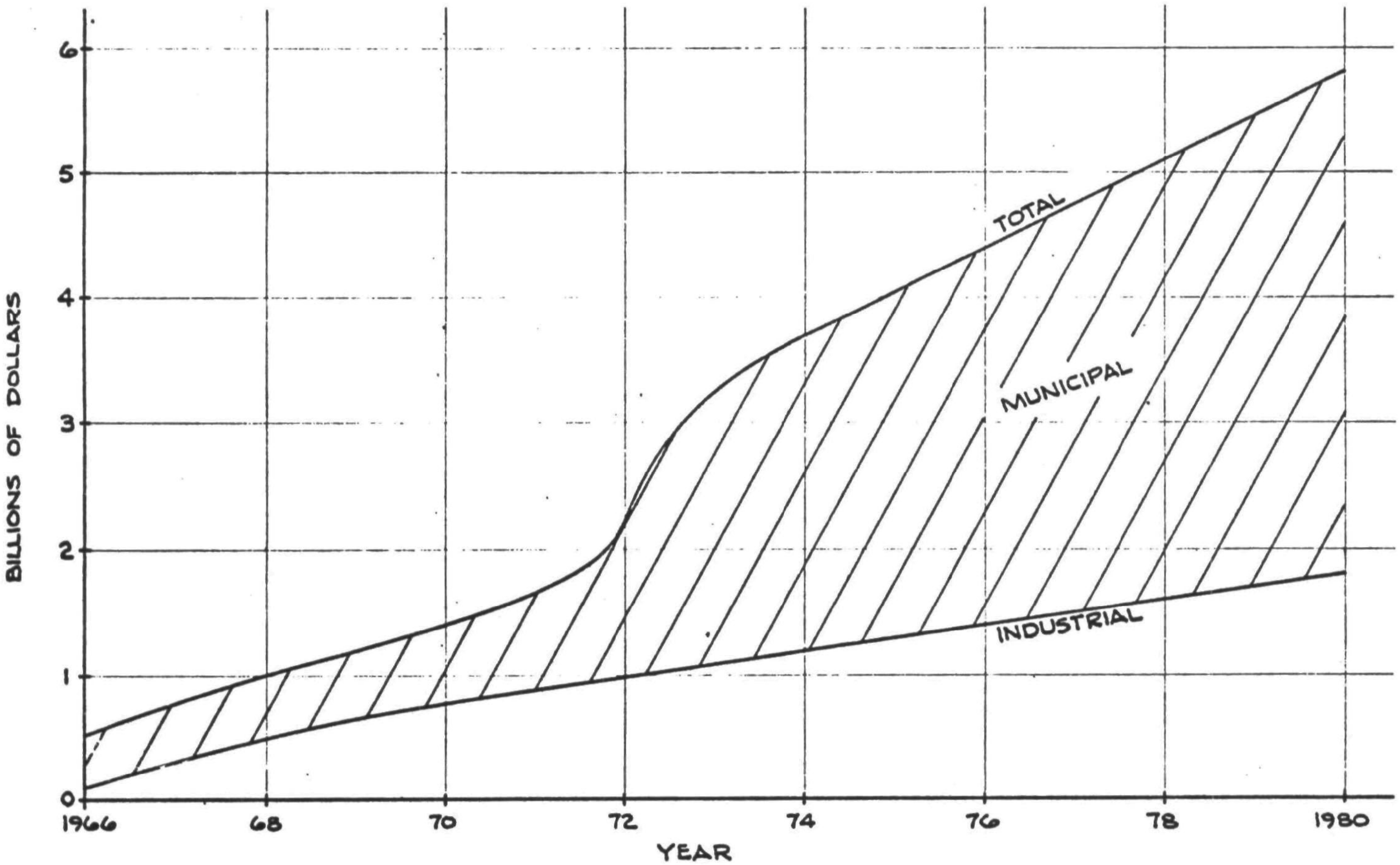

FIGURE 10
TOTAL WATER POLLUTION
CONTROL EXPENDITURES

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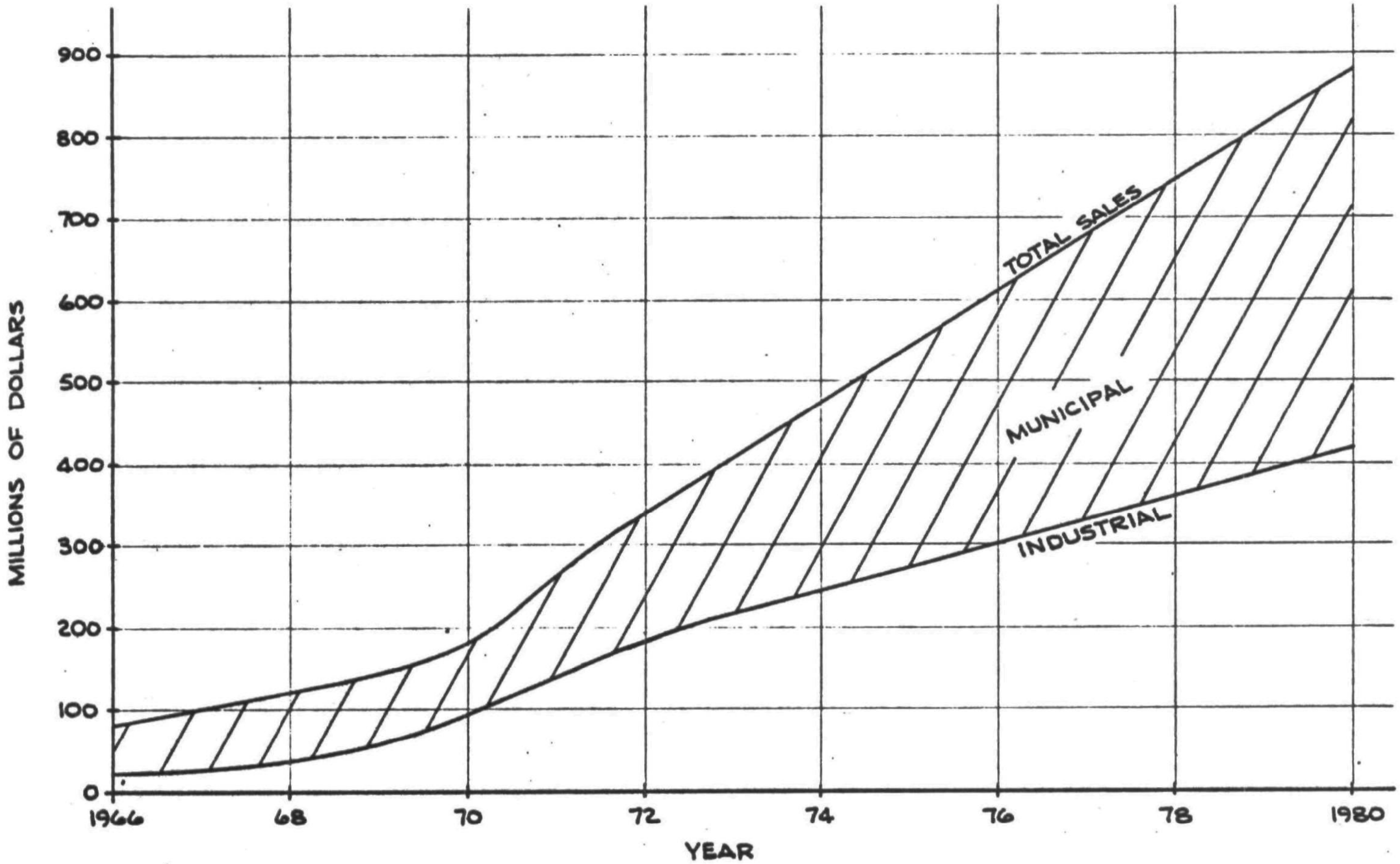

FIGURE 11
WASTEWATER TREATMENT
EQUIPMENT SALES

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There appear to be no substantial geographical limitations to the distribution of waste water treatment equipment to industry. In various areas, certain suppliers may be more successful than others; however, this seems to be more related to the effectiveness of the sales activities rather than to any geographical limitation. The use of independent metal fabricators as subcontractors to manufacture certain pieces of equipment further reduces geographical limitations.

Equipment delivery schedules may vary substantially depending upon the manufacturer, the current demand, and the specific equipment in question. Obviously, the greater the demand or the more specialized the equipment, the greater the delivery time.

Availability of Construction Manpower

After consultation with the Associated General Contractors of America and other industry groups, it is concluded that sufficient manpower exists to construct any required treatment facilities.

This conclusion has reportedly been substantiated by EPA in an independent study (59) although there is still some concern about localized problems. The Bureau of Labor Statistics has been requested to conduct another study.

Construction Cost Index

The most detailed study and careful analysis of cost trends in prior years still leaves much to be desired in predicting construction cost through the next ten years.

During the years 1955 through 1965 there was a very consistent price rise. The Engineering News Record (ENR) Construction Cost Index in January 1955 was 644. With slight deviations from a straight line, costs rose at a steady rate to an index of 988 in December 1965. This represented an increased cost of 53.4 percent over an eleven year period of approximately 5 percent per year.

The first six months of 1966 saw an increase of 6.6. percent then leveled off abruptly only to rise sharply again in 1967 at a rate of 6.2 percent, then increasing to 9.4 percent in 1968.

The increase in costs continued to rise at about 10.5 percent per year through 1970. During 1971, construction costs rose at the unprecedented rate of 15.7 percent primarily due to larger increases in labor rates.

With the application of federal wage and price controls in 1972, the rate of increase dropped to 8.7 percent. The first three months of 1973 saw some escalation of cost due to allowable materials price gains. EPA determined the increase in Treatment Plant Construction Cost during this period to be 3.1 percent. This compares with a rise of only 0.9 percent during the previous three months.

The opinion of some officials of the Associated General Contractors is that the rate of cost increase for general construction work, including waste water treatment and industrial construction, should average no more than five to six percent over the next several years. This is, therefore, the basis used for extension of the ENR index curve at an annual six percent increase for construction costs through the year 1983. This is shown in Figure 12.

Land Requirements

Land requirements for a number of external treatment systems have been evaluated and are shown in Figure 13 for a range of plant sizes. Incineration or off-site disposal of dewatered sludge has been assumed. Should sludge lagoons be used on site, additional land would be required.

Time Required to Construct Treatment Facilities

The time required to construct treatment facilities has been determined for a range of plant sizes and for two different project contract possibilities. The treatment sizes evaluated were under 18,925 kiloliters per day (five MGD), 18,925-189,250 kiloliters per day (five to 10 MGD), and over 189,250 kiloliters per day (10 MGD). The contract bases evaluated were 1) separate engineering and construction and 2) turnkey performance. The components considered for both approaches included preliminary engineering, final design engineering, bid and construction award, and construction.

It is concluded from reviewing the data shown in Figure 14 that it should be possible in all cases to meet the implementation requirements of the July 1977 deadlines.

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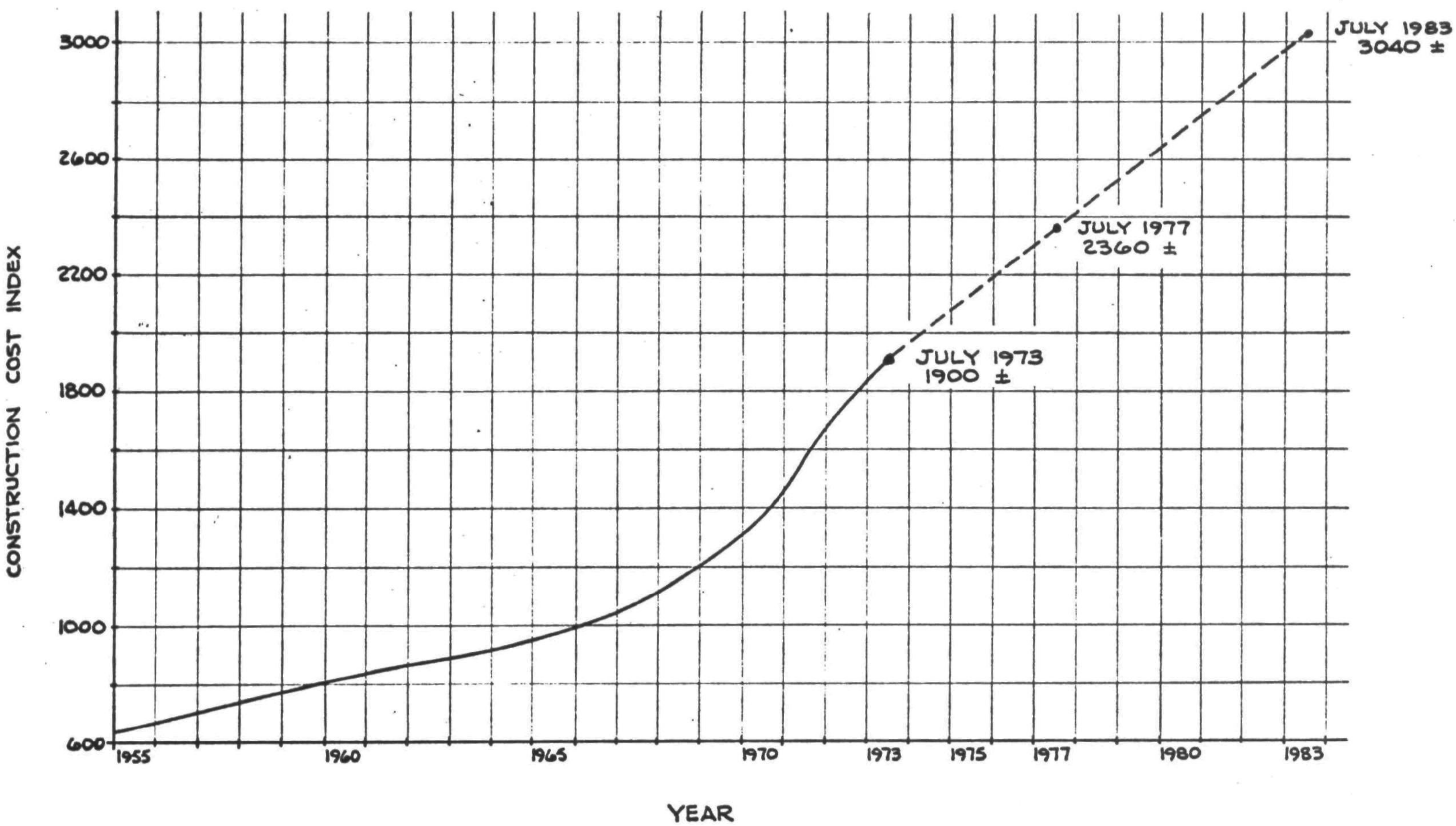


FIGURE 12
ENGINEERING NEWS RECORD
CONSTRUCTION COST INDEX

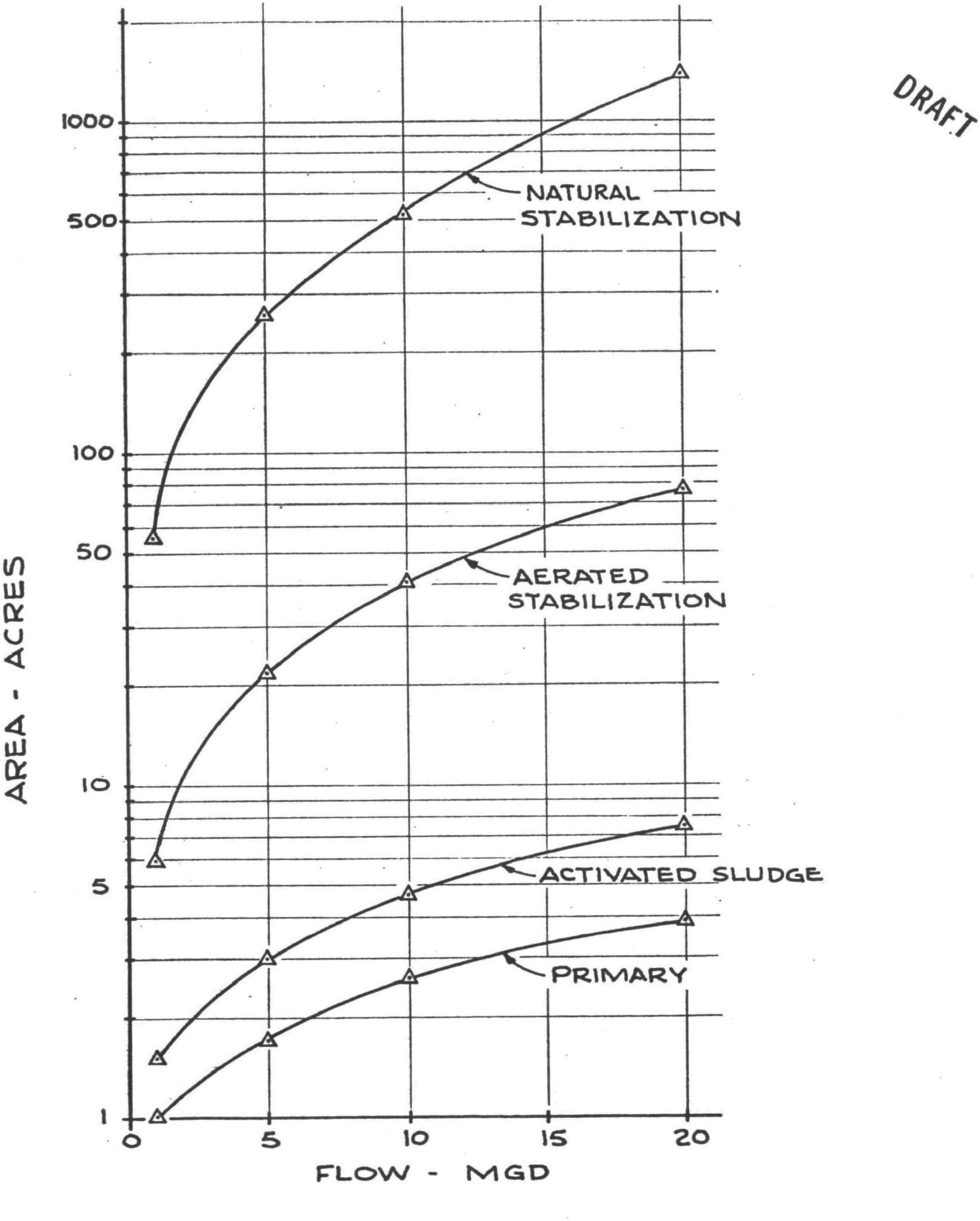
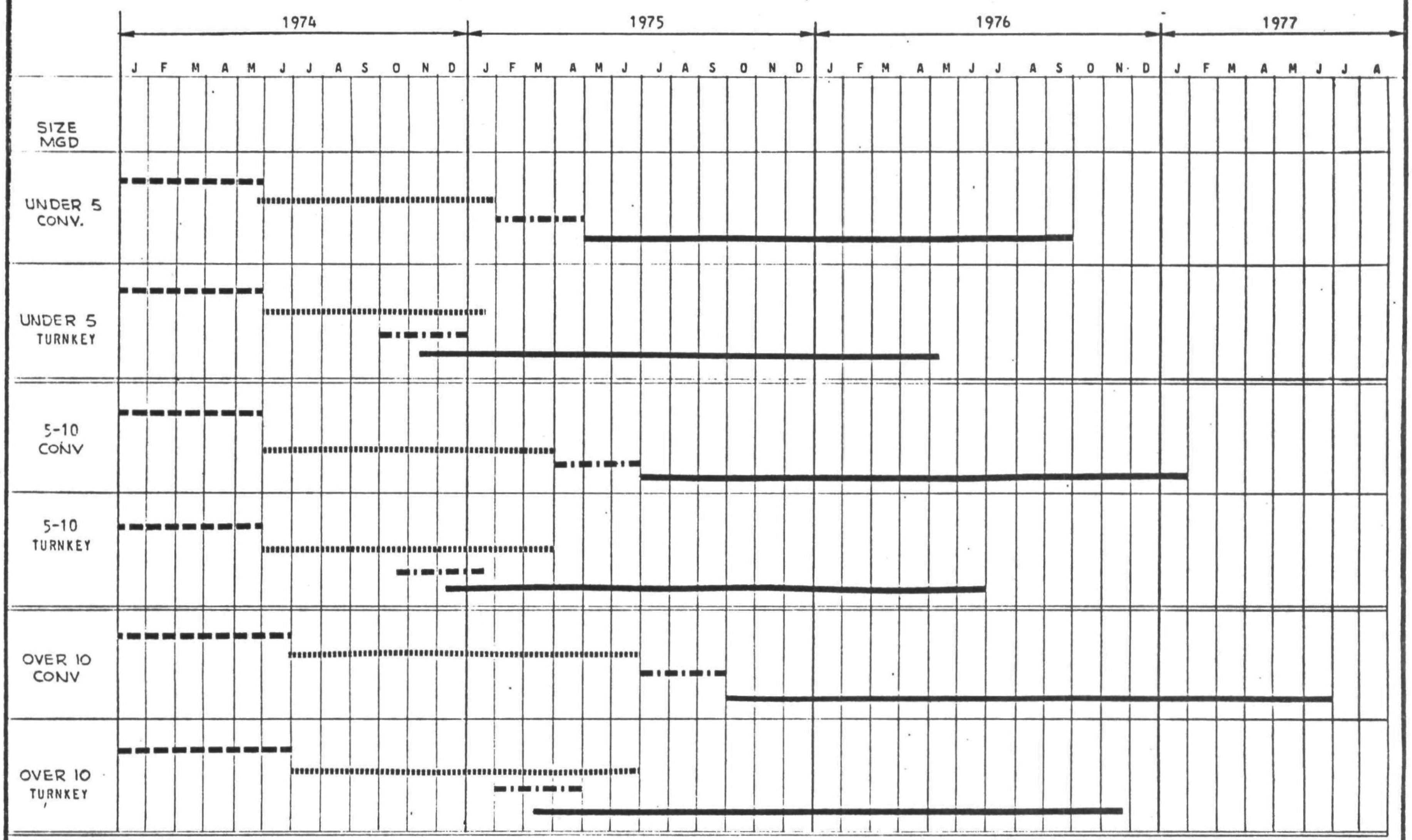


FIGURE 13
LAND REQUIRED FOR
WASTEWATER TREATMENT



PRELIMINARY ENGINEERING

FINAL DESIGN ENGINEERING

BID AND CONSTRUCTION AWARD

CONSTRUCTION

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FIGURE 14

TIME REQUIRED TO CONSTRUCT WASTEWATER FACILITIES CONVENTIONAL & TURNKEY CONTRACTS

SECTION IX

BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

INTRODUCTION

The effluent limitations which must be achieved by July 1, 1977 are to specify the degree of effluent reduction attainable through the application of the best practicable control technology currently available. Best practicable control technology currently available is generally based upon the average of the best existing performance by plants of various sizes, ages, and unit processes within the industrial subcategory.

Consideration was also given to:

a. the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;

b. the size and age of equipment and facilities involved;

c. the processes employed;

d. the engineering aspects of the application of various types of control techniques;

e. process changes;

f. non-water quality environmental impact (including energy requirements).

Also, best practicable control technology currently available emphasizes treatment facilities at the end of a manufacturing process but includes the control technologies within the process itself when the latter are considered to be normal practice within an industry.

A further consideration is the degree of economic feasibility and engineering reliability which must be established for the technology to be "currently available." As a result of demonstration projects, pilot plants, and general use, there must exist a high degree of confidence in the engineering feasibility and economic practicability of the technology at the time of commencement of construction or installation of the control facilities.

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EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF BEST PRACTICABLE POLLUTION CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Based upon the information contained in Sections III through VIII of this report, a determination has been made that the following point source discharge guidelines for each identified pollutant can be obtained through the application of the best practicable pollution control technology currently available. They are given in pounds per short ton of production:

BOD_5	Suspended Solids	pH Range
5.0	3.0	7.5-8.5

The allowable pounds of BOD_5 and suspended solids per ton of production are to be based upon monthly averages of daily values as determined from industrial records. It is expected that values on any given day could exceed these guidelines. Further, values may be adjusted to reflect variations in performance as a result of changes in materials mix, ambient air temperature effect on waste treatment process performance, and other local conditions.

Production capacity is defined as the total production off the machine, including reprocessed broke. Daily production, in air-dry tons, is defined as the highest average level sustained for seven consecutive operating days of normal production.

Values are intended to reflect the net pounds per ton of product which are attributed to the industrial operation, and do not account for "back-ground" pollutional loads which may have existed in the process water prior to use by the industry.

IDENTIFICATION OF BEST POLLUTION CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Internal Control

a. Water Showers

Fresh water showers used to clean wire, felt, and other machine elements (of both fourdrinier and cylinder machines) should be low-volume and high-pressure; white water showers should be low-pressure, high-volume, and self-cleaning.

b. Segregation of White Water Systems

The segregation of white water systems should be designed to permit maximum reuse within the stock preparation/machine systems and to permit only low fiber content white water to enter the sewer.

c. Press Water Filtering

A vibrating or centrifugal screen should be employed to remove felt hairs prior to press water reuse.

d. Collection System for Vacuum Pump Seal Water

Seal water should be collected for partial reuse and/or cascade to or from other water users.

e. Save-all with Associated Equipment

An effective save-all should be employed to recover fibrous and other suspended material which escapes from the paper machine.

f. Gland Water Reduction

Flow control of individual seal water lines to equipment packing glands, or equivalent measures, should be exercised.

External Treatment

a. Suspended Solids Reduction

This step involves removal of suspended solids from the incoming raw waste stream. It can incorporate either 1) an earthen stilling basin; or 2) mechanical clarification and sludge removal. Solids dewatering screens can also be incorporated prior to solids settling as a means of removing coarse solids.

b. BOD reduction

Biological oxidation is to be employed throughout the subject subcategory. Secondary support processes which can also be incorporated are 1) roughing filters and 2) natural oxidation ponds following biological treatment.

c. Secondary solids removal

Where activated sludge is utilized for biological oxidation, secondary mechanical clarification can be utilized for secondary solids removal. Stilling ponds can be incorporated after aerated stabilization basins for removal of secondary solids. Depending upon the design and configuration of the aerated basins, a stilling pond can consist merely of a quiescent zone beyond the influence of aeration equipment, but within the general confines of the aerated basin itself.

d. Sludge disposal

When compatible with other unit processes, sludge disposal can often be carried out in a stilling pond. However, this necessitates periodic dredging, removal, and disposal of solids. Where activated sludge and mechanical clarification are utilized, ultimate sludge disposal can be accomplished through sludge thickening by vacuum filtration or centrifugation, followed by sludge dewatering and ultimate solids disposal. Disposal can be accomplished by either land disposal or incineration. Combustion of sludges can be carried out either in a sludge incinerator or a power boiler.

RATIONALE FOR THE SELECTION OF BEST POLLUTION CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Age and Size of Equipment and Facilities

There is a wide range, in both size and age among mills in the subcategory studied. However, internal operations of most older mills have been upgraded, and some of these mills currently operate very efficiently. The technology for upgrading of older mills is well established, and does not vary significantly from mill to mill within the subcategory. Studies have also shown that waste treatment plant performance does not relate to mill size. Most mills are constructed on a "modular" concept, where key process elements are duplicated as mill size expands. Consequently, there is no significant variation in either the waste water characteristics or in the waste water loading rates, in kilograms per metric ton (in pounds per short ton of product), between mills of varying sizes.

Process Change

Application of best technology currently available does not require major changes in existing industrial processes. Incorporation of additional systems, treatment processes, and control measures can be accomplished in most cases through changes in piping, and through design modifications to existing equipment. Such alterations can be carried out in all mills within the subcategory.

Engineering Aspects of Control Technique Applications

The technology to achieve these effluent limitations is practiced within the subcategory under study. The concepts are proven, available for implementation, and applicable to the wastes in question. The waste treatment techniques are also broadly applied within many other industries. The technology required will necessitate improved monitoring of waste discharges and of waste treatment components on the part of many mills, as well as more extensive training of personnel on operation and maintenance of waste treatment facilities. However, these procedures are currently practiced in some mills and are common practice in many other industries.

Non-water Quality Environmental Impact

Application of the activated sludge waste treatment process offers a potential for adverse impact upon air quality if dewatered sludges are incinerated. However, proper selection and operation of particulate emission control equipment can minimize this impact. Dredged or dewatered sludges disposed of on land can present an odor problem if a solid waste disposal program is not properly implemented. Procedures are available for its control which are utilized where applicable within the subcategory under study or in other industries. Methods for solution of either of these problems do not create significant environmental impacts.

The technology cited will not create any significant increase in noise levels beyond those observed in well designed municipal waste water treatment systems which currently are being approved by the federal government for construction in populated areas. Further, no hazardous chemicals are required as part of this technology.

The greatest proportion of energy consumed will be for pumping and for biological treatment. The total energy requirements for implementation of best available technology are not substantial and should not be sufficient enough to warrant concern on either a national or regional basis. However, it should be cautioned that no investigation has been made in this study on the cumulative effect of energy requirements when all industries within the country simultaneously implement best available technology levels.

Cost of Application in Relation to Effluent Reduction Benefits

For a 90.7 metric ton (100 short ton) per day mill, the total annual cost of this level of technology is estimated at $235,000, including energy requirements. This results in an increase in production costs of $8.60 per metric ton ($7.80 per short ton).

This increase reflects both all internal mill and external waste treatment improvements. It is based on 300 days of production/year. It should be emphasized, however, that most mills have already carried out many of these improvements. Subsequently, their increased costs would be less than those shown above.

Processes Employed

All mills within the subcategory studied utilize the same basic production processes. Although there are deviations in equipment and production procedures, these deviations do not significantly alter either the characteristics or the treatability of the waste water generated.

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SECTION X

BEST AVAILABLE TECHNOLOGY
ECONOMICALLY ACHIEVABLE

INTRODUCTION

Best available technology economically achievable is to be achieved not later than July 1, 1983. It is not based upon an average of the best performance within the subcategory under study, but has been determined by identifying the very best control and treatment technology employed by a specific point source within the subcategory, or by applying technology from other industry areas where it is transferrable.

Consideration was also given to:

a. the age of equipment and facilities involved;

b. the process employed;

c. the engineering aspects of the application of various types of control techniques;

d. process changes;

e. cost of achieving the effluent reduction resulting from application of the technology;

f. non-water quality environmental impact, including energy requirements.

This level of technology emphasizes both internal process improvements and external treatment of waste waters. It will, therefore, require existing mills to implement significant internal changes on water reuse and recycle as well as to apply more advanced waste treatment processes and other improved internal and external controls in order to meet the suggested effluent guidelines. In some cases, the industry may be required to conduct applied research and demonstration studies in order to firmly establish the most economical approach toward meeting the guidelines.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Based upon the information contained in Sections III through VIII of this report, a determination has been made that the following point source discharge guidelines for each identified pollutant can be obtained through the application of best available technology. They are expressed in pounds per ton of production.

BOD_5	Suspended Solids	pH Range
2.5	1.5	7.5-8.5

The allowable pounds of BOD_5 and suspended solids per ton of production are to be based upon monthly averages of daily values as determined from industrial records. It is expected that values on any given day could exceed these guidelines. Further, values may be adjusted to reflect variations in performance as a result of changes in materials mix, ambient air temperature, effect on waste treatment process performance, and other local conditions.

Production capacity is defined as the total production off the machine, including reprocessed broke. Daily production, in air-dry tons, is defined as the highest average level sustained for seven consecutive operating days of normal production.

Values are intended to reflect the net pounds per ton of product which are attributed to the industrial operation, and do not account for "background" pollutional loads which may have existed in the process water prior to use by the industry.

IDENTIFICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

The best available technology economically achievable consists of the best practicable control technology currently available as defined in Section IX of this report. It also includes the following additional internal mill improvements and external advanced waste water treatment practices.

Internal Controls

Building paper operations will be able to implement modifications and operating procedures for:

a. control of spills whereby major pollutional loads bypass the waste water treatment system to a retention basin and are ultimately either reused, gradually discharged into the treatment system, or treated separately;

b. intensive internal reuse of process waters;

c. separation of cooling waters from other waste water streams, and subsequent heat removal and reuse;

d. intensive reduction of gland water spillage.

External Treatment

Section IX of the report describes best practicable external control technology currently available. Application of that technology in conjunction with several additional recognized and potential technologies described in section VII constitutes best available technology economically achievable. The additional external processes applicable to this more advanced technology are as follows:

a. suspended solids removal through either coagulation and flocculation followed by settling, filtration, or reverse osmosis;

b. BOD_5 reduction through the application of two-stage biological treatment;

c. trace organics removal through either carbon adsorption or chlorination.

RATIONALE FOR THE SELECTION OF BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Age and Size of Equipment and Facilities

There is a wide range, in both size and age, among mills in the subcategory studied. However, internal operations of most older mills have been upgraded, and some of these mills currently operate very efficiently. The technology for upgrading of older mills is well established, and does not vary significantly from mill to mill. Studies have also shown that waste treatment plant performance does not relate to mill size. Most mills are constructed on a "modular" concept, where key process elements are duplicated as mill size expands. Consequently, there is no significant variation in either the waste water characteristics or in the waste water loading rates, in kilograms per metric ton ton (in pounds per short ton of product), between mills of varying sizes.

Process Changes

Application of best available technology economically achievable does not require major changes in existing industrial processes. Incorporation of additional systems, treatment processes, and control measures can be accomplished in most cases through changes in piping, and through design modifications to existing equipment. Such alterations can be carried out on all mills within the subcategory.

Engineering Aspects of Control Technique Applications

The technology to achieve most of these effluent limitations is either practiced by an outstanding mill in the subcategory, or is demonstrated in other industries and is transferrable. The technology required for all best available treatment and control systems will necessitate sophisticated monitoring, sampling, and control programs, as well as properly trained personnel.

Non-water Quality Environmental Impact

Application of the activated sludge waste treatment process offers a potential for adverse impact upon air quality if dewatered sludges are incinerated. However, proper selection and operation of particulate emission control equipment can minimize this impact. Dredged or dewatered sludges disposed of on land can present an odor problem if a solid waste disposal program is not properly implemented. Procedures are available for its control which are utilized where applicable within the subcategory or in other industries. Methods for solution of either of these problems do not create significant environmental impacts.

The technology cited will not create any significant increase in noise levels beyond those observed in well designed municipal waste water treatment systems which currently are being approved by the federal government for construction in populated areas. Further, no hazardous chemicals are required as part of this technology.

The greatest proportion of energy consumed will be for pumping and for biological treatment. The total energy requirements for implementation of best available technology for the categories under study are not substantial and should not be sufficient enough to warrant concern on either a national or regional basis. However, it should be cautioned that no investigation has been made in this study on the cumulative effect of energy requirements when all industries within the country simultaneously implement best available technology levels.

Cost of Application in Relation to Effluent Reduction Benefits

Based upon the information contained in Section VIII of this report, total projected cost of upgrading a 90.7 metric ton (100 short ton)per day mill incorporating best practicable control technology currently available to the level of best achievable technology economically feasible reflects an increase in production expenses of $11.58 per metric ton ($10.50 per short ton). This is based upon total annual cost of $315,000, including energy requirements.

This increase reflects both all internal mill and external waste treatment improvements and is based on 300 days of production per year.

Processes Employed

All mills within the subcategory studied utilize the same basic production processes. Although there are deviations in equipment and production procedures, these deviations do not significantly alter either the characteristics or the treatability of the waste water generated.

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SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

INTRODUCTION

This level of technology is to be achieved by new sources. The term "new source" is defined in the Act to mean "any source, the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance." Such commencement of construction can occur within the near future, certainly before either the 1977 or 1983 compliance dates for either best practicable or best achievable technologies. Therefore, new source performance standards utilize best practicable control technology currently available as a base, but also encompass additional treatment and control technologies through the application of improved production processes which are designed to reduce pollutant loads.

Consideration has also been given to:

a. The type of process employed and process changes;
b. Operating methods;
c. Batch as opposed to continuous operations;
d. Use of alternative raw materials and mixes of raw materials;
e. Use of dry rather than wet processes (including substitution of recoverable solvents for water);
f. Recovery of pollutants as byproducts; and
g. Pre-treatment requirements for discharges to municipal systems.

RECOMMENDED NEW SOURCE STANDARDS OF PERFORMANCE

Based upon the information contained in Sections III through VIII of this report, the following standards of performance are recommended:

Pounds Per Short Ton of Production

BOD_5	Suspended Solids	pH Range
4.0	2.5	7.5-8.5

The allowable pounds of BOD_5 and suspended solids per ton of production are to be based upon monthly averages of daily values as determined from industrial records. It is expected that values on any given day could exceed these guidelines. Further, values may be adjusted to reflect variations in performance as a result of changes in materials mix, ambient air temperature effect on waste treatment process performed, and other local conditions.

Production capacity is defined as the total production off the machine, including reprocessed broke. Daily production, in air dry tons, is defined as the highest average level sustained for seven consecutive operating days of normal production.

Values are intended to reflect the net pounds per ton of product which are attributed to the industrial operation, and do not account for "background" pollutional loads which may have existed in the process water prior to use by the industry.

IDENTIFICATION OF TECHNOLOGY FOR NEW SOURCE PERFORMANCE STANDARDS

The technology for new source performance standards consists of the best practicable control technology currently available as defined in Section IX of this report. It also includes limited application of additional internal mill improvements and external advanced waste water treatment practices as defined in Section X of this report for best available technology economically achievable.

It is expected that "new source" mills will not be able to realize maximum efficiency in the limited application of best available technology economically achievable since additional study is required before the full potential of some of the technologies can be identified. However, "new source" mills have an advantage over existing mills in the achievement of optimum recycle segregation, and selective use and reuse systems. These improvements can be more readily incorporated into new mill designs than into existing mills which must be modified.

RATIONALE FOR SELECTION OF TECHNOLOGY FOR NEW SOURCE PERFORMANCE STANDARDS

Type of Process Employed and Process Changes

No radical new in-plant processes are proposed as a means of achieving new source performance standards for this subcategory.

Operating Methods

Significant revisions in operating methods, both in-plant and at the waste water treatment facility, will be necessary. However, these improvements are not beyond the scope of well-trained personnel, and are currently being practiced in other industries. The primary areas of operational change will pertain to required activities for recycle, reuse, and spill control, as well as for optimal performance of waste water treatment facilities.

Batch as Opposed to Continuous Operations

For the subcategory studied, it was determined that batch as opposed to continuous operations is not a significant factor in waste load. characteristics and no additional control of pollutants could be achieved through the use of one type process over the other.

Use of Alternative Raw Materials and Mixes of Raw Materials

The raw materials requirements for a given mill do vary, depending upon supply and demand, desired end product, and other conditions. However, alteration of raw materials as a means of reducing pollutants is not considered feasible over the long term even though such a change could possibly realize benefits of short duration in a given instance.

Use of Dry Rather than Wet Processes (Including Substitution of Recoverable Solvents for Water)

For this subcategory, it was determined that technology for dry pulping beyond that already practiced or papermaking processes does not exist nor is it in a sufficiently viable experimental stage to be considered here.

Recovery of Pollutants as Byproducts

It is anticipated that these performance standards will motivate increased research on recovering materials for byproduct sale the recovery of which is not presently economically feasible.

Pre-treatment Requirements for Discharges to Municipal Systems

None of the pollutant parameters identified in Section VI of this report, with the possible exception of pH, can be expected to disrupt or interfere with the normal operation of a municipal waste water treatment system which is designed to accommodate the industrial pollutant load discharge to it from any mill within the subcategory studied. In the case of pH, some pre-treatment may be required if it can be shown that the normal pH range in the waste discharged from a given mill exceeds 6-8.5.

SECTION XII

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SECTION XIII

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SECTION XIV

GLOSSARY

<u>Act</u>

Federal Water Pollution Control Act, as amended in 1972.

<u>Air Dry Ton</u>

Measurement of production including moisture content, which usually varies between four and ten percent.

<u>Attrition Mill</u>

A refiner containing fixed and rotating discs which fiberizes wood chips.

<u>Broke</u>

Partly or completely manufactured paper that does not leave the machine room as salable paper or board; also paper damaged in finishing operations such as rewinding rolls, cutting, and trimming.

<u>Cellulose</u>

The fibrous constituent of trees.

<u>Chest</u>

A tank used for storage of wet fiber or furnish.

<u>Chips</u>

Small pieces of wood used to make pulp.

<u>Coatings</u>

Materials such as clay, starch, alum, synthetic adhesives, etc., applied to the surface of paper to impart special characteristics.

<u>Color Unit</u>

A measure of color concentration in water using APHA methods.

<u>Consistency</u>

The weight percent of solids in a solids-water mixture used in the manufacture of pulp or paper.

Cylinder Machine

A papermaking machine in which the sheet is formed on a wire-covered cylinder rotating in a vat of furnish.

Decker or Thickener

A mechanical device used to remove water from pulp.

Digester

A pressure vessel used to soften wood chips in the presence of water and heat.

External Treatment

Technology applied to raw waste streams to reduce pollutant levels.

Fiber

The cellulosic portion of the tree used to make paper.

Furnish

The mixture of fibers and chemicals used to manufacture paper.

Gland

A device utilizing a soft wear resistant material used to minimize leakage between a rotating shaft and the stationary portion of a vessel such as a pump.

Gland Water

Water used to lubricate a gland. Sometimes called "packing water."

Grade

The type of building paper or felt manufactured.

In-Plant Measures

Technology applied within the manufacturing process to reduce or eliminate pollutant in the raw waste water. Sometimes called "internal measures."

Level I

Best practicable control technology.

Level II

Best available technology economically achievable.

Level III

New source performance standards.

Machine Felt

An endless belt of wool or plastic used to convey and dewater the sheet during the papermaking process.

Pulp

Cellulosic fibers from wood chips, waste paper, or other fiber sources.

Pulper or Beater

A mechanical device used to separate fiber bundles in the presence of water prior to papermaking.

Rejects

Material unsuitable for papermaking which has been separated in the manufacturing process.

Save-all

A mechanical device used to recover papermaking fibers and other suspended solids from a waste water or process stream.

Sheet

The web of paper as manufactured on a paper machine.

Stock

Wet pulp with or without chemical additions.

Suction Box

A rectangular box with holes or slots on its top surface, used to suck water out of a felt or paper sheet by the application of vacuum.

Virgin Wood Pulp (or fiber)

Pulp made from wood, as contrasted to waste paper sources of fiber.

White Water

Water which drains through the wires of a paper machine which contains fiber, filler, and chemicals.

Cylinder

A wire wound open-faced drum, mounted in paper machine vat, on which the paper is formed into a sheet.

Press

A device using two rolls for pressing water from the sheet and/or the felts carrying the sheet, prior to drying.

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APPENDIX I

62 BUILDING PAPER AND ROOFING FELT MILLS IN THE U.S.

Saturated/Coated Roofing Felt

GAF Corp.
Mobile, Alabama

Bear Brand Roofing, Inc.
Bearden, Arkansas

Celotex Corp.
Camden, Arkansas

A-R Felt Mills, Inc.
Little Rock, Arkansas

Elk Roofing Co.
Stephens, Arkansas

Fry Roofing Co.
Compton, California

Celotex Corp.
Los Angeles, California

Certain-Teed Products Corp.
Richmond, California

Anchor Paper Mills, Inc.
South Gate, California

Reynolds Metals Co.
Stratford, Connecticut

Fry Roofing Co.
Jacksonville, Florida

Fry Roofing Co.
Miami, Florida

GAF Corp.
Savannah, Georgia

Bird & Son, Inc.
Chicago, Illinois

Flintkote Co.
Mt. Carmel, Illinois

Carey Co.
Wimington, Illinois

Fry Roofing Co.
Brookville, Indiana

Fry Roofing Co.
Mishawaka, Indiana

Bird & Son, Inc.
Shreveport, Louisiana

Atlas Roofing Mfg. Co., Inc.
Meridian, Mississippi

Tamko Asphalt Products Inc.
Joplin, Missouri

GAF Corp.
Kansas City, Missouri

Fry Roofing Co.
N. Kansas City, Missouri

U.S. Gypsum Co.
Jersey City, New Jersey

Fry Roofing Co.
Morehead City, North Carolina

Certain-Teed Products Corp.
Milan, Ohio

Big Chief Roofing Co.
Ardmore, Oklahoma

Allied Materials Corp.
Strand, Oklahoma

Bird & Son Inc. of Mass.
Portland, Oregon

Fry Roofing Co.
Portland, Oregon

DRAFT

APPENDIX I, Contd.

Saturated/Coated Roofing Felt, Contd.

Fry Roofing Co.
Emmaus, Pennsylvania

Celotex Corp.
Philadelphia, Pennsylvania

Certain Teed Products Corp.
York, Pennsylvania

Fry Roofing Co.
Memphis, Tennessee

GAF Corp.
Dallas, Texas

Southern Johns-Manville Corp.
Ft. Worth, Texas

Carey Co.
Houston, Texas

Fry Roofing Co.
Houston, Texas

Fry Roofing Co.
Irving, Texas

Celotex Corp.
San Antonio, Texas

Dry Roofing Felt

Fontana Paper Mills Inc.
Fontana, California

Celotex Corp.
Peoria, Illinois

Royal Brand Roofing, Inc. (Tamko)
Phillipsburg, Kansas

GAF Corp.
Gloucester City, New Jersey

Carey Co.
Perth Amboy, New Jersey

Conwed Corp.
Riverside, New Jersey

Conwed Corp.
Cloquet, Minnesota

Asbestos Paper & Gasket

Johns-Manville Products Corp.
Pittsburg, California

Carey Co.
Cincinnati, Ohio

Nicolet Industries, Inc.
Hamilton, Ohio

Filter Materials, Inc.
Sandusky, Ohio

Nicolet Industries, Inc.
Norristown, Pennsylvania

Armstrong Cork Co.
Fulton, New York

DRAFT

APPENDIX I, Contd.

Combination of the Above

GAF Corp.
Joliet, Illinois

Johns-Manville Perlite Corp.
Joliet, Illinois

Grace & Co.
Owensburg, Kansas

U.S. Gypsum Co.
Lisbon Falls, Maine

Latex Fiber Industries, Inc.
Camden, New Jersey

Carey Co.
Linden, New Jersey

Logan-Long Co.
Franklin, Ohio

Malarkey Paper Co.
Portland, Oregon

Nicolet Industries, Inc.
Ambler, Pennsylvania