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EPA Office of Compliance Sector Notebook Project

Profile of the Pulp and Paper Industry
2nd Edition

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Office of Compliance
Office of Enforcement and Compliance Assurance
U.S. Environmental Protection Agency
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This report is one in a series of volumes published by the U.S. Environmental Protection Agency (EPA) to provide information of general interest regarding environmental issues associated with specific industrial sectors. The documents were developed under contract by Abt Associates (Cambridge, MA), GeoLogics Corporation (Alexandria, VA), Science Applications International Corporation (McLean, VA), and Booz-Allen & Hamilton, Inc. (McLean, VA). A listing of available Sector Notebooks is included on the following page.

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The Sector Notebooks were developed by the EPA's Office of Compliance. Direct general questions about the Sector Notebook Project to:

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For further information, and for answers to questions pertaining to these documents, please refer to the contacts listed on the following page.

AVAILABLE SECTOR NOTEBOOKS

Questions and comments regarding the individual documents should be directed to Compliance Assistance and Sector Programs Division at 202 564-2310 unless otherwise noted below. **See the Notebook web page at: http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/ for the most recent titles and links to refreshed data.**

EPA Publication Number	Industry
EPA/310-R-95-001.	Profile of the Dry Cleaning Industry
EPA/310-R-95-002.	Profile of the Electronics and Computer Industry*
EPA/310-R-95-003.	Profile of the Wood Furniture and Fixtures Industry
EPA/310-R-95-004.	Profile of the Inorganic Chemical Industry*
EPA/310-R-95-005.	Profile of the Iron and Steel Industry
EPA/310-R-95-006.	Profile of the Lumber and Wood Products Industry
EPA/310-R-95-007.	Profile of the Fabricated Metal Products Industry*
EPA/310-R-95-008.	Profile of the Metal Mining Industry
EPA/310-R-95-009.	Profile of the Motor Vehicle Assembly Industry
EPA/310-R-95-010.	Profile of the Nonferrous Metals Industry
EPA/310-R-95-011.	Profile of the Non-Fuel, Non-Metal Mining Industry
EPA/310-R-02-001.	Profile of the Organic Chemical Industry, 2nd Edition*
EPA/310-R-95-013.	Profile of the Petroleum Refining Industry
EPA/310-R-95-014.	Profile of the Printing Industry
EPA/310-R-02-002.	Profile of the Pulp and Paper Industry, 2nd Edition
EPA/310-R-95-016.	Profile of the Rubber and Plastic Industry
EPA/310-R-95-017.	Profile of the Stone, Clay, Glass, and Concrete Ind.
EPA/310-R-95-018.	Profile of the Transportation Equipment Cleaning Ind.
EPA/310-R-97-001.	Profile of the Air Transportation Industry
EPA/310-R-97-002.	Profile of the Ground Transportation Industry
EPA/310-R-97-003.	Profile of the Water Transportation Industry
EPA/310-R-97-004.	Profile of the Metal Casting Industry
EPA/310-R-97-005.	Profile of the Pharmaceuticals Industry
EPA/310-R-97-006.	Profile of the Plastic Resin and Man-made Fiber Ind.
EPA/310-R-97-007.	Profile of the Fossil Fuel Electric Power Generation Industry
EPA/310-R-97-008.	Profile of the Shipbuilding and Repair Industry
EPA/310-R-97-009.	Profile of the Textile Industry
EPA/310-R-97-010.	Sector Notebook Data Refresh-1997 **
EPA/310-R-98-001.	Profile of the Aerospace Industry
EPA/310-R-00-001.	Profile of the Agricultural Crop Production Industry Contact: Ag Center, (888) 663-2155
EPA/310-R-00-002.	Profile of the Agricultural Livestock Production Industry Contact: Ag Center, (888) 663-2155
EPA/310-R-00-003.	Profile of the Agricultural Chemical, Pesticide and Fertilizer Industry Contact: Agriculture Division, 202 564-2320
EPA/310-R-00-004.	Profile of the Oil and Gas Extraction Industry
	Government Series
EPA/310-R-99-001.	Profile of Local Government Operations

* Spanish translations available of 1st Editions in electronic format only.

** This document revises compliance, enforcement, and toxic release inventory data for all previously published profiles. Visit the Sector Notebook web page to access the most current data.

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Pulp and Paper Industry
(SIC 2611 through 2631)

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LIST OF ACRONYMS

AFS	AIRS Facility Subsystem (CAA database)
AIRS	Aerometric Information Retrieval System (CAA database)
AOR	Area of Review (SDWA)
AOX	Adsorbable Organic Halides
BAT	Best Available Technology Economically Achievable
BCT	Best Conventional Pollutant Control Technology
BIFs	Boilers and Industrial Furnaces (RCRA)
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
BPT	Best Practicable Technology Currently Available
CAA	Clean Air Act
CAAA	Clean Air Act Amendments of 1990
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CERCLIS	CERCLA Information System
CFCs	Chlorofluorocarbons
CFR	Code of Federal Regulations
CGP	Construction General Permit (CWA)
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CSI	Common Sense Initiative
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
D&B	Dun and Bradstreet Marketing Index
DOC	United States Department of Commerce
EIS	Environmental Impact Statement
EPA	United States Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ESA	Endangered Species Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FINDS	Facility Indexing System
FR	Federal Register
FRP	Facility Response Plan
HAPs	Hazardous Air Pollutants (CAA)
HSDB	Hazardous Substances Data Bank
HSWA	Hazardous and Solid Waste Amendments
IDEA	Integrated Data for Enforcement Analysis
LDR	Land Disposal Restrictions (RCRA)
LEPCs	Local Emergency Planning Committees
MACT	Maximum Achievable Control Technology (CAA)
MCLGs	Maximum Contaminant Level Goals
MCLs	Maximum Contaminant Levels
MEK	Methyl Ethyl Ketone
MSDSs	Material Safety Data Sheets

MSGP	Multi-Sector General Permit (CWA)
NAAQS	National Ambient Air Quality Standards (CAA)
NAFTA	North American Free Trade Agreement
NAICS	North Americal Industrial Classification System
NCDB	National Compliance Database (for TSCA, FIFRA, EPCRA)
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEC	Not Elsewhere Classified
NEIC	National Enforcement Investigation Center
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NICE[3]	National Industrial Competitiveness Through Energy, Environment and Economics
NO_2	Nitrogen Dioxide
NOI	Notice of Intent
NOT	Notice of Termination
NOV	Notice of Violation
NO_x	Nitrogen Oxides
NPDES	National Pollution Discharge Elimination System (CWA)
NPL	National Priorities List
NRC	National Response Center
NSPS	New Source Performance Standards (CAA)
OAQPS	Office of Air Quality Planning and Standards
OAR	Office of Air and Radiation
OECA	Office of Enforcement and Compliance Assurance
OMB	Office of Management and Budget
OPA	Oil Pollution Act
OPPTS	Office of Prevention, Pesticides, and Toxic Substances
OSHA	Occupational Safety and Health Administration
OSW	Office of Solid Waste
OSWER	Office of Solid Waste and Emergency Response
OW	Office of Water
P2	Pollution Prevention
PCS	Permit Compliance System (CWA Database)
PM10	Particulate Matter of 10 microns or less
PMN	Premanufacture Notice
POTW	Publicly Owned Treatments Works
PSD	Prevention of Significant Deterioration (CAA)
PT	Total Particulates
RCRA	Resource Conservation and Recovery Act
RCRIS	RCRA Information System
RQ	Reportable Quantity (CERCLA)
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SEPs	Supplementary Environmental Projects
SERCs	State Emergency Response Commissions
SIC	Standard Industrial Classification
SIP	State Implementation Plan

SO_2	Sulfur Dioxide
SO_x	Sulfur Oxides
SPCC	Spill Prevention Control and Countermeasures
STEP	Strategies for Today's Environmental Partnership
SWPPP	Storm Water Pollution Prevention Plan (CWA)
TOC	Total Organic Carbon
TRI	Toxic Release Inventory
TRIS	Toxic Release Inventory System
TCRIS	Toxic Chemical Release Inventory System
TSCA	Toxic Substances Control Act
TSD	Treatment Storage and Disposal
TSP	Total Suspended Particulates
TSS	Total Suspended Solids
UIC	Underground Injection Control (SDWA)
USDW	Underground Sources of Drinking Water (SDWA)
UST	Underground Storage Tanks (RCRA)
VOCs	Volatile Organic Compounds

I. INTRODUCTION TO THE SECTOR NOTEBOOK PROJECT

I.A. Summary of the Sector Notebook Project

Environmental policies based upon comprehensive analysis of air, water and land pollution (such as economic sector, and community-based approaches) are an important supplement to traditional single-media approaches to environmental protection. Environmental regulatory agencies are beginning to embrace comprehensive, multi-statute solutions to facility permitting, compliance assurance, education/outreach, research, and regulatory development issues. The central concepts driving the new policy direction are that pollutant releases to each environmental medium (air, water and land) affect each other, and that environmental strategies must actively identify and address these interrelationships by designing policies for the "whole" facility. One way to achieve a whole facility focus is to design environmental policies for similar industrial facilities. By doing so, environmental concerns that are common to the manufacturing of similar products can be addressed in a comprehensive manner. Recognition of the need to develop the industrial "sector-based" approach within the EPA Office of Compliance led to the creation of this document.

The Sector Notebook Project was initiated by the Office of Compliance within the Office of Enforcement and Compliance Assurance (OECA) to provide its staff and managers with summary information for eighteen specific industrial sectors. As other EPA offices, states, the regulated community, environmental groups, and the public became interested in this project, the scope of the original project was expanded. The ability to design comprehensive, common sense environmental protection measures for specific industries is dependent on knowledge of several interrelated topics. For the purposes of this project, the key elements chosen for inclusion are: general industry information (economic and geographic); a description of industrial processes; pollution outputs; pollution prevention opportunities; federal statutory and regulatory framework; compliance history; and a description of partnerships that have been formed between regulatory agencies, the regulated community and the public.

For any given industry, each topic listed above could alone be the subject of a lengthy volume. However, in order to produce a manageable document, this project focuses on providing summary information for each topic. This format provides the reader with a synopsis of each issue, and references where more in-depth information is available. Text within each profile was researched from a variety of sources, and was usually condensed from more detailed sources pertaining to specific topics. This approach allows for a wide coverage of activities that can be further explored based upon the references listed at the end of this profile. As a check on the information included, each notebook went through an external document review process. The Office of Compliance appreciates the efforts of all those that participated in this process and enabled us to develop more complete, accurate and up-to-date summaries. Many of those who reviewed this notebook are listed as contacts in Section IX and may be sources of additional information. The individuals and groups on this list do not necessarily concur with all statements within this notebook.

I.B. Additional Information

Providing Comments

OECA's Office of Compliance plans to periodically review and update the notebooks and will make these updates available both in hard copy and electronically. If you have any comments on the existing notebook, or if you would like to provide additional information, please send a hard copy and computer disk to the EPA Office of Compliance, Sector Notebook Project (2224-A), 1200 Pennsylvania Ave., NW, Washington, DC 20460. Comments can also be sent via the Sector Notebooks web page at: http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/. If you are interested in assisting in the development of new Notebooks, or if you have recommendations on which sectors should have a Notebook, please contact the Office of Compliance at 202-564-2310.

Adapting Notebooks to Particular Needs

The scope of the industry sector described in this notebook approximates the national occurrence of facility types within the sector. In many instances, industries within specific geographic regions or states may have unique characteristics that are not fully captured in these profiles. The Office of Compliance encourages state and local environmental agencies and other groups to supplement or re-package the information included in this notebook to include more specific industrial and regulatory information that may be available. Additionally, interested states may want to supplement the "Summary of Applicable Federal Statutes and Regulations" section with state and local requirements. Compliance or technical assistance providers may also want to develop the "Pollution Prevention" section in more detail.

II. INTRODUCTION TO THE PULP AND PAPER INDUSTRY

This section provides background information on the size, geographic distribution, employment, production, sales, and economic condition of the pulp and paper industry. Facilities described within the document are also described in terms of their Standard Industrial Classification (SIC) codes.

II.A. Introduction, Background, and Scope of the Notebook

The paper and allied products industry (SIC 26) comprises two types of facilities: pulp and paper mills that process raw wood fiber or recycled fiber to make pulp and/or paper, and converting facilities that use these primary materials to manufacture more specialized products such as paperboard boxes, writing paper, and sanitary paper. Portions of this notebook present information for all of SIC 26, but the notebook focuses primarily on the greatest areas of environmental concern within the industry: those from pulpmaking processes. Converting facilities are not discussed, and the papermaking stage of the pulp and paper process is de-emphasized.

The specific industry components covered in this industry are the following:

SIC 2611. Pulp mills. Pulp mills separate the fibers of wood or from other materials, such as rags, linters, wastepaper, and straw in order to create pulp. Mills may use chemical, semi-chemical, or mechanical processes, and may create co-products such as turpentine and tall oil.

This SIC code does not include pulpmaking facilities that are part of an integrated paper or paperboard facility; those would be categorized according to the appropriate final product. The following are types of pulp mills included in this SIC code:

- Deinking of newsprint
- Fiber pulp: made from wood, rags, wastepaper, linters, straw, and bagasse
- Pulp mills
- Pulp: soda, sulfate, sulfite, groundwood, rayon, and semichemical
- Rayon pulp
- Wood pulp

SIC 2621. Paper mills. Paper mills primarily are engaged in manufacturing paper from woodpulp and other fiber pulp, and may also manufacture converted paper products. Establishments primarily engaged in integrated operations of producing pulp and manufacturing paper are included in this industry if primarily shipping paper or paper products. Establishments primarily engaged in manufacturing converted paper products from purchased paper stock are classified in Industry Group 265 or Industry Group 267.

SIC 2631. Paperboard mills. Establishments in this SIC code primarily are engaged in manufacturing paperboard, including paperboard coated on the paperboard machine, from wood pulp and other fiber pulp; and may also manufacture converted paperboard products. Establishments primarily engaged in manufacturing converted paperboard products from purchased paperboard are classified in Industry Group 265 or Industry Group 267. Establishments primarily engaged in manufacturing insulation board and other reconstituted wood fiberboard are classified in Industry 2493.

The following SIC codes are within SIC 26, but are not addressed in detail in this document:

SIC 265 (2652-2657). Paperboard containers and boxes. Establishments in these SIC codes are engaged in the manufacture of corrugated and solid fiber boxes and containers from purchased paperboard. The principal commodities of this industry are boxes, pads, partitions, display items, pallets, corrugated sheets, food packaging, and non-food (e.g., soaps, cosmetics, and medicinal products) packaging.

SIC 267 (2671-2679). Miscellaneous converted paper products. These establishments produce a range of paper, paperboard, and plastic products with purchased material. Common products include paper and plastic film packaging, specialty paper, paper and plastic bags, manila folders, sanitary paper products, envelopes, stationery, and other products.

SIC codes were established by the Office of Management and Budget (OMB) to track the flow of goods and services within the economy. OMB has changed the SIC code system to a system based on similar production processes called the North American Industrial Classification System (NAICS). Because most of the data presented in this notebook apply to the pulp and paper industry as defined by its SIC codes, this notebook continues to use the SIC system to define this sector. Table 1 presents the SIC codes for the pulp and paper industry and the corresponding NAICS codes.

Table 1: SIC and NAICS Codes

1987 SIC	SIC Description	1997 NAICS	NAICS Description
2611	Pulp mills	322110	Pulp mills
2621	Paper mills	322121	Paper (except newsprint) mills (part)
		322122	Newsprint mills
2631	Paperboard mills	322130	Paperboard mills
2652	Setup paperboard boxes	322213	Setup paperboard box mfg
2653	Corrugated & solid fiber boxes	322211	Corrugated & solid fiber box mfg
2655	Fiber cans, drums & similar products	322214	Fiber cans, drums & similar products mfg
2656	Sanitary food containers	322215	Nonfolding sanitary food container mfg
2657	Folding paperboard boxes	322212	Folding paperboard box mfg
2671	Paper - coated & laminated, packaging	322221	Coated & laminated packaging paper & plastics film mfg
		326112	Unsupported plastics packaging film & sheet mfg
2672	Paper - coated & laminated, n.e.c.	322222	Coated & laminated paper mfg (part)
2673	Bags - plastics, laminated, & coated	322223	Plastics, foil, & coated paper bag mfg
		326111	Unsupported plastics bag mfg
2674	Bags - uncoated paper & multiwall	322224	Uncoated paper & multiwall bag mfg
2675	Die-cut paper & board	322226	Surface-coated paperboard mfg
		322231	Die-cut paper & paperboard office supplies mfg (part)
		322299	All other converted paper product mfg (part)
2676	Sanitary paper products	322121	Paper (except newsprint) mills (part)
		322291	Sanitary paper product mfg (part)
2677	Envelopes	322232	Envelope mfg
2678	Stationery products	322233	Stationery, tablet, & related product mfg
2679	Converted paper products, n.e.c.	322222	Coated & laminated paper mfg (part)
		322231	Die-cut paper & paperboard office supplies mfg (part)
		322299	All other converted paper product mfg (part)

Source: U.S. Census Bureau, 2000a.

II.B. Characterization of the Pulp and Paper Industry

The pulp and paper industry converts wood (harvested by logging firms in SIC 24) or recycled fiber into pulp and primary forms of paper. Other companies in the paper and allied products industry (SIC codes 265 and 267) use the products of the pulp and paper industry to manufacture specialized products including paperboard boxes, writing paper, and sanitary paper.

II.B.1. Product Characterization

The pulp and paper industry produces primary products – commodity grades of wood pulp, printing and writing papers, sanitary tissue, industrial-type papers, containerboard and boxboard – using cellulose fiber from timber or purchased or recycled fibers. The two steps are pulping and paper or paperboard manufacturing.

Pulping

Pulping is the process of dissolving wood chips into individual fibers by chemical, semi-chemical, or mechanical methods. The particular pulping process used affects the strength, appearance, and intended use characteristics of the resultant paper product. Pulping is the major source of environmental impacts in the pulp and paper industry. There are more than a dozen different pulping processes in use in the U.S.; each pulping process has its own set of process inputs, outputs, and resultant environmental concerns. Table 2 provides an overview of the major pulping processes and the main products that they produce.

Table 2: Description of Pulping Processes

Pulp Process	Description/Principal Products
Dissolving Kraft	Highly bleached and purified kraft process wood pulp suitable for conversion into products such as rayon, viscose, acetate, and cellophane.
Bleached Papergrade Kraft and Soda	Bleached or unbleached kraft process wood pulp usually converted into paperboard, coarse papers, tissue papers, and fine papers such as business, writing and printing.
Unbleached Kraft	
Dissolving Sulfite	Highly bleached and purified sulfite process wood pulp suitable for conversion into products such as rayon, viscose, acetate, and cellophane.

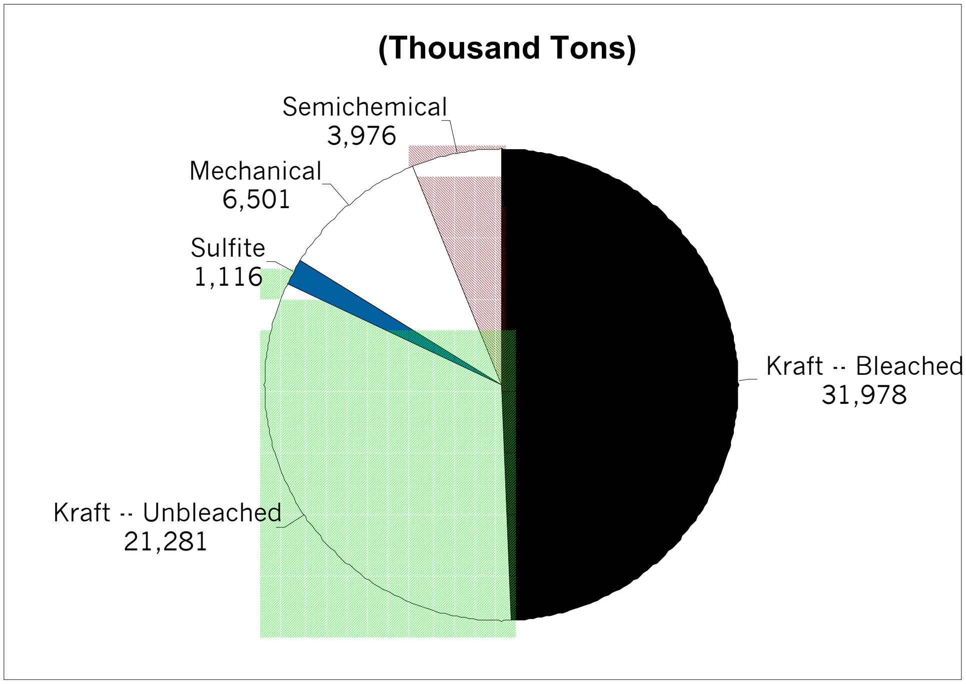
Table 2: Description of Pulping Processes (continued)

Pulp Process	Description/Principal Products
Papergrade Sulfite	Sulfite process wood pulp with or without bleaching used for products such as tissue papers, fine papers, and newsprint.
Semi-chemical	Pulp is produced by chemical, pressure, and occasionally mechanical forces with or without bleaching used for corrugating medium (cardboard), paper, and paperboard.
Mechanical pulp	Pulp manufacture by stone groundwood, mechanical refiner, thermo-mechanical, chemi-mechanical, or chemi-thermo-mechanical means for newsprint, coarse papers, tissue, molded fiber products, and fine papers.
Secondary Fiber Deink	Pulps from recovered paper or paperboard using a chemical or solvent process to remove contaminants such as inks, coatings and pigments used to produce fine, tissue, and newsprint papers.
Secondary Fiber Non-deink	Pulp production from recovered paper or paperboard without deinking processes to produce tissue, paperboard, molded products and construction papers.
Non-wood Chemical pulp	Production of pulp from textiles (e.g.,rags), cotton linters, flax, hemp, tobacco, and abaca to make cigarette wrap papers and other specialty paper products.

Source: U.S. EPA, 1993a.

The bleached and unbleached kraft processes are used to manufacture the majority of paper products. Together, these processes account for 83 percent of the pulp produced in the United States. Figure 1 presents the relative output of the major pulping processes.

Figure 1: Pulp Production, 2000



Source: AF&PA, 2001.

The pulp manufacturing process is the major source of environmental concern for this industry. For example, a bleached kraft pulp mill requires 4,000-12,000 gallons of water and 14-20 million Btu of energy per ton of pulp, of which roughly 8-10 million Btu typically are derived from biomass-derived fuel from the pulping process (*Pulp and Paper*, 2001). Across all facilities in SIC 26, the pulp, paper, and allied products industry is the largest consumer of process water and the third largest consumer of energy (behind the chemicals and metals industries) (U.S. Department of Commerce, 2000 and U.S. Department of Energy, 2000). The high use of water and energy, as well as the chemical inputs described in Section III, lead to a variety of environmental concerns.

Paper and Paperboard Manufacturing

The paper or paperboard manufacturing process is similar for all types of pulp. In this process, pulp is spread out as a wet mixture, or *slurry*, onto a screen. Water is removed by gravity and vacuums, and the resulting layer of fibers is passed through a series of rollers that compress the material into sheets. Paper and paperboard manufacturers use nearly identical processes; the difference is that paperboard is thicker (more than 0.3 mm).

II.B.2. Industry Size and Geographic Distribution

The pulp and paper industry is characterized by very large facilities; of the 514 pulp and paper mills in SIC codes 261-263 reported by the Bureau of the Census in 1998, 343 (67 percent) have 100 or more employees. Across all of these facilities, there are 172,000 employees who produced $59 billion in shipments (in 1998 dollars). In 2000, the industry employed 182,000 and produced $79 billion in shipments.

In contrast, the downstream facilities (container and specialty product manufacturers) tend to be more numerous but smaller. More than 75 percent of these facilities have fewer than 100 employees. Table 3 presents the employment distribution for both pulp and paper facilities and downstream manufacturers in 1997 (the most recent data available) as reported by the U.S. Census Bureau. Because recent years have seen some facility closures, the current number of facilities may be somewhat lower.

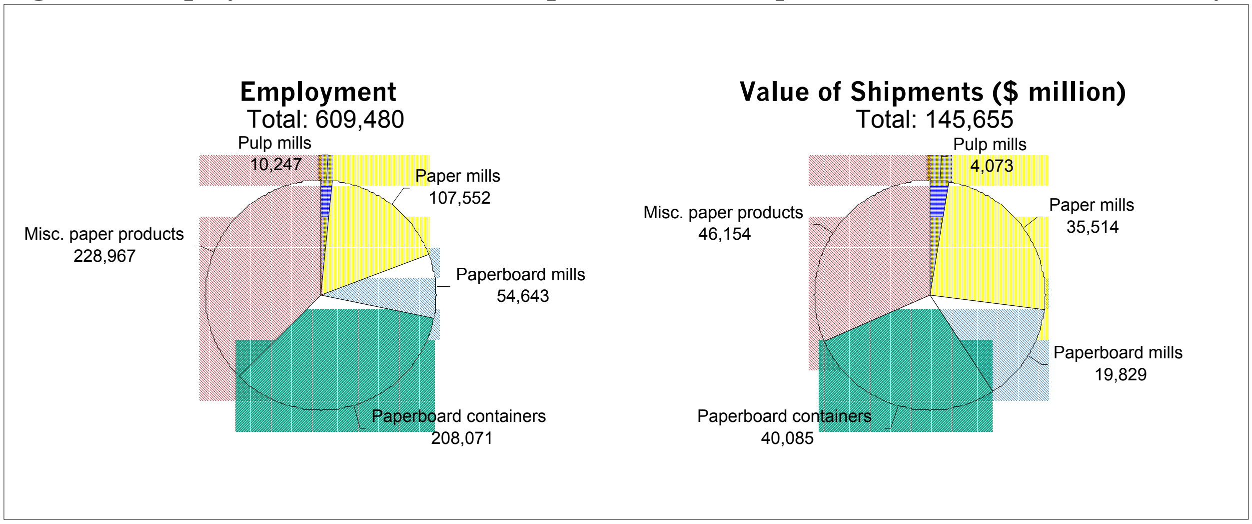
Table 3: Size of Paper and Allied Products Facilities

Industry	Employees per Facility (% of Total)			
	1-19	20-99	100-499	>499
Pulp mills (SIC 261)	3 (7%)	14 (34%)	18 (44%)	6 (15%)
Paper mills (SIC 262)	6 (2%)	63 (24%)	107 (41%)	83 (32%)
Paperboard mills (SIC 263)	8 (4%)	77 (36%)	96 (45%)	33 (15%)
Paperboard containers and boxes (SIC 265)	748 (26%)	1,311 (46%)	782 (27%)	14 (<1%)
Misc. converted paper products (SIC 267)	1,383 (44%)	1,116 (36%)	597 (19%)	70 (2%)

Source: U.S. Census Bureau, 1998.

Figure 2 presents the employment and value of shipments for both the primary and secondary portions of the paper and allied products industry. Taken together, the industry is among the top 10 U.S. manufacturing industries in value of shipments. As noted in the two graphs, the pulp and paper portion of the industry (pulp, paper, and paperboard mills) employs only 28 percent of the workers in the industry, but produces over 40 percent of the shipments.

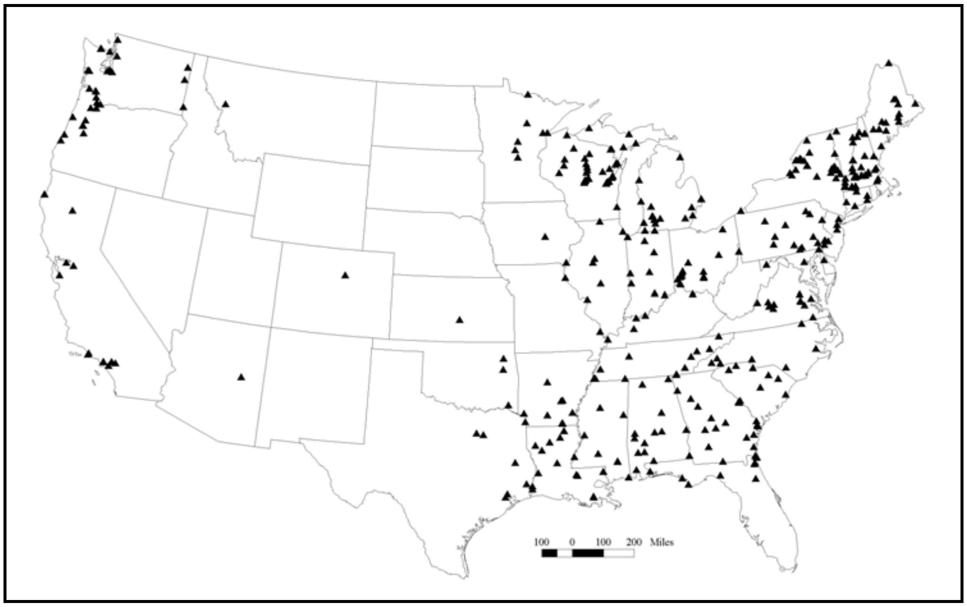
Figure 2: Employment and Value of Shipments in the Paper and Allied Products Industry[a]



[a] Integrated mills, which produce both pulp and paper (or paperboard), are included in the paper (or paperboard) categories. The pulp mill category includes only facilities producing pulp for the general market.
Source: U.S. Census Bureau, 2000b.

The geographic distribution of pulp and paper mills varies according to the type of mill. As there are tremendous variations in the scale of individual facilities, tallies of the number of facilities may not represent the level of economic activity (nor possible environmental consequences). Pulp mills are located primarily in regions of the country where trees are harvested from natural stands or tree farms: the Southeast, Northwest, Northeast, and North Central regions. Pulp mills that process recycled fiber are generally located near sources of waste paper. Paper mills, however, are more widely distributed. They are located near pulping operations and/or near converting markets. The distribution of paperboard mills reflects the location of manufacturing in general, since such operations are the primary market for paperboard products. Figure 3 presents the location of pulp and paper mills in the U.S.

Figure 3: Geographic Distribution of Pulp, Paper, and Paperboard Mills



There are no currently active mills in Alaska or Hawaii.
Source: U.S. EPA, 1999.

II.B.3. Economic Trends

World Market Competition

The U.S. produces roughly 30 percent of the world's paper and paperboard. The pulp and paper industry is one of the most important industries for the balance of trade in the U.S. This trade balance increased through most of the 1990s. In 1999, exports from SIC codes 261-263 were $8.5 billion. In recent years, however, exports have been declining and imports have been increasing. Between 1997 and 2000, exports declined 5.5% and imports increased by more than 20%. The declining exports and increasing imports are partly due to a strong dollar in this period and the recent slow down of the U.S. economy (AF&PA, 2001).

The U.S. industry has several advantages over the rest of the world market, including modern mills, a highly skilled work force, a large domestic market, and an efficient transportation infrastructure. Major export markets for pulp are Japan, Italy, Germany, Mexico, and France. The U.S. Department of Commerce anticipates exports to grow faster than production for domestic markets through 2004. World Trade Organization (WTO) efforts to reduce tariffs include those on pulp and paper products; if these are successful, the U.S. industry expects pulp and paper export rates to increase even further.

However, pulp and paper are commodities and therefore prices are vulnerable to global competition. Countries such as Brazil, Chile, and Indonesia have built modern, advanced pulp facilities. These countries have faster-growing trees and lower labor costs. Latin American and European countries also are adding papermaking capacity. Furthermore, the strong value of the dollar has made imports less expensive relative to domestically-produced goods. Because of this increased foreign competition, imports of paper to the U.S. market are expected to increase three percent annually through 2004 (U.S. Department of Commerce, 2000).

Industry Consolidation

In order to compensate for this increasingly competitive market, pulp and paper companies have undertaken a considerable number of mergers and acquisitions. Table 4 lists the major transactions that occurred between 1997 and 2002.

Table 4: Major Pulp and Paper Mergers and Acquisitions

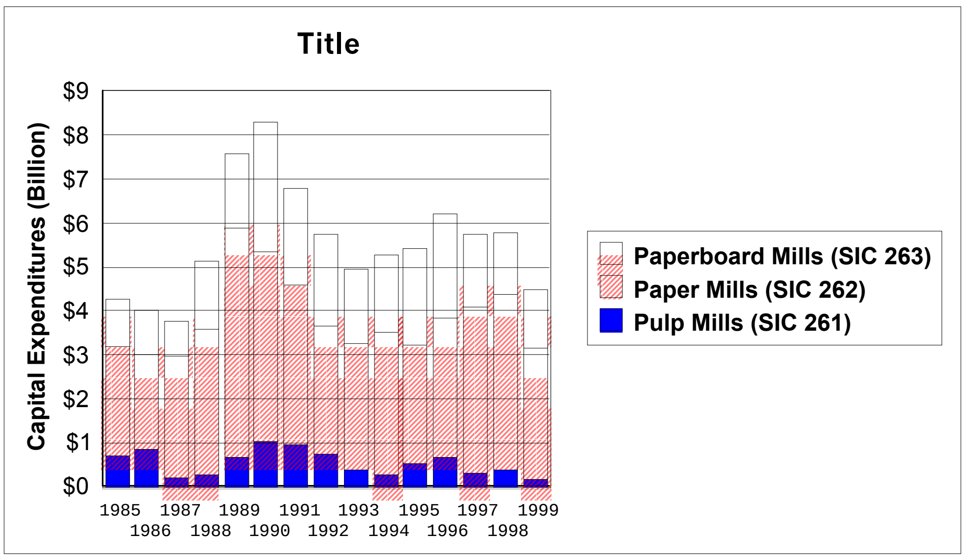
Buyer	Acquired	Value (million)	Year
International Paper Co.	Champion International Inc.	$9,600	2000
International Paper Co.	Union Camp Corp.	$7,900	1999
Jefferson Smurfit Corp.	Stone Container Corp.	$6,400	1998
Weyerhaeuser Co.	Willamette	$6,000	2002
Fort Howard Corp.	James River Corp.	$5,800	1997
Abitibi-Consolidated Inc.	Donohue Inc.	$5,300	2000
Stora Enso Oy	Consolidated Papers Inc.	$4,800	2000
Abitibi-Price Inc.	Stone-Consolidated Inc.	$3,600	1997
Westvaco	Mead	$3,000	2002
Bowater Inc.	Avenor Inc.	$2,500	1997
Weyerhaeuser Co.	MacMillan Bloedel Ltd.	$2,450	1999
Madison Dearborn Industries Inc.	Tenneco Packaging Inc.	$2,200	1999

Largest mergers and acquisitions between 1997 and mid-2000.
Source: McLaren, J et al., 2000, and Pulp & Paper International, September 2002.

Capital Improvements

Historically, U.S. pulp and paper companies have invested heavily in capital improvements to their facilities. Capital investments in recent years, however, are well below historic levels due to the difficult market conditions. For the first time, industry capacity actually declined in 2001 (Pulp & Paper International, 2002). Because few new mills are being built, most capital expenditures represent plant expansions, upgrades, and environmental protection initiatives at existing facilities. Figure 4 presents the rate of capital investments within SIC 261-263. Throughout the time period shown, capital improvements related to environmental protection claimed from 4% to 22% of the total investments with significant increases in the early and late 1990s (AF&PA, 2001).

Figure 4: Capital Improvements at Pulp and Paper Mills

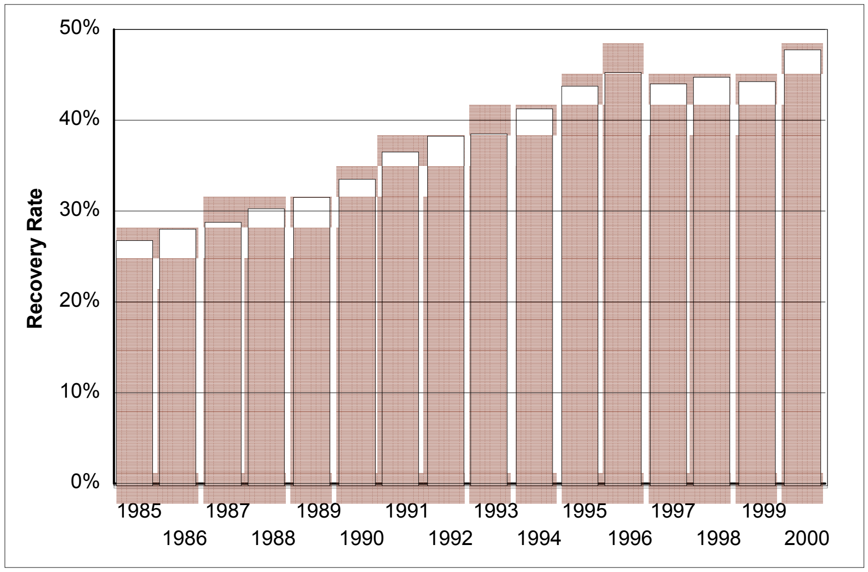


Source: AF&PA, 2001.

Recycling Efforts

A major movement within the pulp and paper industry has been an increased focus on the use of recovered paper. As shown in Figure 5, nearly 50 percent of paper now is recovered and used either as recycled paper or as products such as home insulation. Furthermore, recovered paper contributes to U.S. exports; roughly ten million tons of recovered paper were exported in 2000 (AF&PA, 2001).

Figure 5: Paper Recovery Rates



The recovery rate is the ratio of recovered paper collected to new supply of paper and paperboard.
Source: AF&PA, 2001.

III. INDUSTRIAL PROCESS DESCRIPTION

This section describes the major industrial processes within the pulp and paper industry, including the materials and equipment used, and the processes employed. The section is designed for those interested in gaining a general understanding of the industry, and for those interested in the inter-relationship between the industrial process and the topics described in subsequent sections of this profile -- pollutant outputs, pollution prevention opportunities, and Federal regulations. This section does not attempt to replicate published engineering information that is available for this industry. Refer to Section IX for a list of reference documents that are available.

This section specifically contains a description of commonly used production processes, associated raw materials, the byproducts produced or released, and the materials either recycled or transferred off-site. This discussion, coupled with schematic drawings of the identified processes, provides a concise description of where wastes may be produced in the process. This section also describes the potential fate (via air, water, and soil pathways) of these waste products.

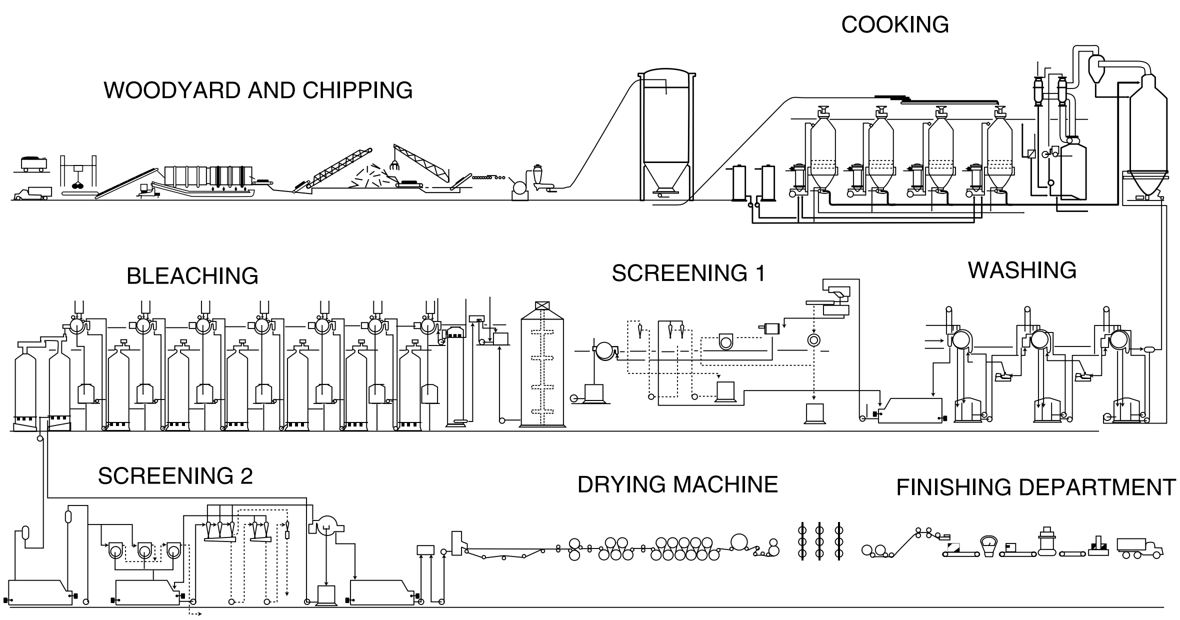
III.A. Industrial Processes in the Pulp and Paper Industry

Simply put, paper is manufactured by applying a watery suspension of cellulose fibers to a screen which allows the water to drain and leaves the fibrous particles behind in a sheet. Most modern paper products contain non-fibrous additives, but otherwise fall within this general definition. Only a few paper products for specialized uses are created without the use of water, via dry forming techniques. The individual fibers formed into paper sheets is called pulp. The production of pulp is the major source of environmental impacts in the pulp and paper industry.

Processes in the manufacture of paper and paperboard can, in general terms, be split into three steps: pulp making, pulp processing, and paper/paperboard production. Paperboard sheets are thicker than paper sheets; paperboard is thicker than 0.3 mm. In general, however, paper and paperboard production processes are identical. First, a stock pulp mixture is produced by digesting a material into its fibrous constituents via chemical, mechanical, or a combination of chemical and mechanical means. In the case of wood, the most common pulping material, chemical pulping actions release cellulose fibers by selectively destroying the chemical bonds in the glue-like substance (lignin) that binds the fibers together. After the fibers are separated and impurities have been removed, the pulp may be bleached to improve brightness and processed to a form suitable for paper-making equipment. At the paper-making stage, the pulp can be combined with dyes, strength building resins, or texture adding filler materials, depending on the intended end product. Afterwards, the mixture is dewatered, leaving the fibrous constituents and pulp additives on a wire or wire-mesh conveyor. Additional additives may be applied after the sheet-making step. The fibers bond together as they are carried through a series of presses and heated rollers. The final paper product is usually spooled on large rolls for storage (see Figure 6).

The following discussion focuses mainly on pulping processes due to their importance in understanding industry environmental impacts and current industry regulatory classification schemes. If more information on papermaking processes is desired, the *Development Document for Proposed Effluent Limitations, Guidelines and Standards for the Pulp and Paper Industry, Point Source Category* (EPA-821-R-93-019) is recommended. Additional sources are listed in Section IX of this document.

Figure 6: Simplified Flow Diagram: Integrated Mill (Chemical Pulping, Bleaching, and Paper Production)



Source: Smook, 1992.

III.A.1. Pulp Manufacture

At the pulping stage, the processed furnish (wood or other fiber source) is digested into its fibrous constituents. The bonds between fibers may be broken chemically, mechanically, or by a combination of the techniques called semi-chemical pulping. The choice of pulping technique is dependent on the type of furnish and the desired qualities of the finished product, but chemical pulping is the most prevalent. Table 5 presents an overview of the wood pu00lping types by the method of fiber separation, resultant fiber quality, and percent of 1998 U.S. pulp production. Many mills perform multiple pulping processes at the same site, most frequently non-deink secondary fiber pulping and papergrade kraft pulping (U.S. EPA, 1993a). The three basic types of wood pulping processes 1) chemical pulping, 2) semi-chemical pulping, and 3) mechanical pulping are detailed below followed by a discussion of secondary fiber pulping techniques.

Table 5: General Classification of Wood Pulping Processes

Process Category	Fiber Separation Method	Fiber Quality	Examples	% of Total 1998 US Wood Pulp Production
Mechanical	Mechanical energy	Short, weak, unstable, impure fibers	Stone groundwood, refiner mechanical pulp	10%
Semi-chemical	Combination of chemical and mechanical treatments	"Intermediate" pulp properties (some unique properties)	High-yield kraft, high-yield sulfite	6%
Chemical	Chemicals and heat	Long, strong, stable fibers	Kraft, sulfite, soda	84%

Sources: Smook, 1992; AF&PA, 1999.

A variety of technologies and chemicals are used to manufacture pulp, but most pulp manufacturing systems contain the process sequence shown in Table 6.

Table 6: Pulp Manufacturing Process Sequence

Process Sequence	Description
Fiber Furnish Preparation and Handling	Debarking, slashing, chipping of wood logs and then screening of wood chips/secondary fibers (some pulp mills purchase chips and skip this step)
Pulping	Chemical, semi-chemical, or mechanical breakdown of pulping material into fibers
Pulp Processing	Removal of pulp impurities, cleaning and thickening of pulp fiber mixture
Bleaching	Addition of chemicals in a staged process of reaction and washing increases whiteness and brightness of pulp, if necessary
Pulp drying and baling (non-integrated mills)	At non-integrated pulp mills, pulp is dried and bundled into bales for transport to a paper mill
Stock Preparation	Mixing, refining, and addition of wet additives to add strength, gloss, texture to paper product, if necessary

Overall, most of the pollutant releases associated with pulp and paper mills occur at the pulping and bleaching stages where the majority of chemical inputs occur.

Furnish Composition

Furnish is the blend of fibrous materials used to make pulp. According to the *1990 National Census of Pulp, Paper, and Paperboard Manufacturing Facilities*, the most commonly used furnish material is wood; it is used in some form by approximately 95 percent of pulp and paper manufacturers. Overall, wood furnish averages approximately 50 percent of pulp content industry-wide.

The major source of fiber for paper products comes from the vegetative tissues of vascular plants. Although almost any vascular plant could be used for paper production, the economics of scale require a high fiber yield for paper manufacture. By far, the principle source of paper-making fibers in the United States is wood from trees, the largest vascular plants available. The fibrous particles used to make paper are made of cellulose, a primary component of the cell walls of vascular plant tissues. The cellulose fibers must be removed from a chemical matrix (e.g., lignin, hemicelluloses, and resins) and result in a mixture of relatively pure fibers.

Wood used to make pulp can arrive at the mill in a variety of forms including wood logs, chips, and sawdust. Due to different physical and chemical properties of different types of wood, certain pulping processes are most efficient on specific wood types. The type of wood used can also make a difference in the final characteristics of the pulp. In general, softwood (e.g., pine and spruce) fibers are longer than those from hardwood (e.g., birch and oak) and have thinner cell walls. The longer fibers of softwood promote inter-fiber bonding and produce papers of greater strength.

Secondary fibers comprise the next most common furnish constituent. Secondary fibers consist of pre-consumer fibers (e.g., mill waste fibers) and post-consumer fiber. Post-consumer fiber sources are diverse, but the most common are newsprint and corrugated boxes (See Table 7). Although secondary fibers are not used in as great a proportion as wood furnish, approximately 80 percent of pulp and paper manufacturers use some secondary fibers in their pulp production and approximately 200 mills (approximately 40 percent of total number of mills) rely exclusively on secondary fibers for their pulp furnish (AF&PA, 1999; AF&PA, 2000c). Secondary fibers must be processed to remove contaminants such as glues or bindings, but, depending on the end product, may or may not be processed to remove ink contaminants or to brighten the pulp.

Secondary fiber use is increasing in the pulp and paper industry due to consumer demand for products made from recycled paper. Recovered fiber accounted for 75 percent of the industry's increase in fiber consumption between 1990 and 2000 (AF&PA, 2000a). The utilization of secondary fibers, expressed as the ratio of recovered paper consumption to the total production of paper and paperboard, is at approximately 39 percent and is climbing slowly (AF&PA, 2001). In a resource-deficient country such as Japan, the secondary fiber utilization rate is at about 50 percent, whereas the average utilization rate in Europe is approximately 40 percent (VDP, 1997). Due to losses of fiber substance and strength during the recycling process, a 50 percent utilization rate is considered the present maximum overall utilization rate for fiber recycling (Smook, 1992).

Secondary fiber sources are seldom used as feedstocks for high quality paper products. Contaminants (e.g., inks, paper colors) are often present, so production of low-purity products is often the most cost-effective use of secondary fibers, although decontamination technologies are available. Approximately 68 percent of all secondary fiber in the U.S. is presently used for multi-ply paperboard or the corrugating paper used to manufacture corrugated cardboard (AF&PA, 2000a). Over the next decade, an increasing proportion of the total amount will be deinked for newsprint or other higher-quality uses.

Table 7: Relative Wastepaper Usage as Secondary Fiber in 1999

Paper Type	% of Total Wastepaper Usage in 1999
Mixed Paper	18%
Old Newspaper	19%
Old Corrugated Cardboard	48%
Pulp Substitutes	6%
High-grade Deinked	9%

Source: AF&PA, 2000b.

Other types of furnish include cotton rags and linters, flax, hemp, bagasse, tobacco, and synthetic fibers such as polypropylene. These substances are not used widely, however, as they are typically for low volume, specialty grades of paper.

The types of furnish used by a pulp and paper mill depend on the type of product produced and what is readily available. Urban mills use a larger proportion of secondary fibers due to the post-consumer feedstock close at hand. More rurally located mills are usually close to timber sources and thus may use virgin fibers in greater proportion.

Furnish Preparation

Furnish is prepared for pulp production by a process designed to supply a homogenous pulping feedstock. In the case of roundwood furnish (logs), the logs are cut to manageable size and then debarked. At pulp mills integrated with lumbering facilities, acceptable lumber wood is removed at this stage. At these facilities, any residual or waste wood from lumber processing is returned to the chipping process; in-house lumbering rejects can be a significant source of wood furnish at a facility. The bark of those logs not fit for lumber is usually either stripped mechanically or hydraulically with high powered water jets in order to prevent contamination of pulping operations. Depending on the moisture content of the bark, it may then be burned for energy production. If not burned for energy production, bark can be used for mulch, ground cover, or to make charcoal.

Hydraulic debarking methods may require a drying step before burning. Usually, hydraulically removed bark is collected in a water flume, dewatered, and pressed before burning. Treatment of wastewater from this process is difficult and costly, however, whereas dry debarking methods can channel the removed bark directly into a furnace (Smook, 1992). In part because of these challenges, hydraulic debarking has decreased in significance within the industry (Potlatch, 2002).

Debarked logs are cut into chips of equal size by chipping machines. Chippers usually produce uniform wood pieces 20 mm long in the grain direction and 4 mm thick. The chips are then put on a set of vibrating screens to remove those that are too large or small. Large chips stay on the top screens and are sent to be recut, while the smaller chips are usually burned with the bark. Certain mechanical pulping processes, such as stone groundwood pulping, use roundwood; however, the majority of pulping operations require wood chips. Non-wood fibers are handled in ways specific to their composition. Steps are always taken to maintain fiber composition and thus pulp yield.

Chemical Pulping

Chemical pulps are typically manufactured into products that have high-quality standards or require special properties. Chemical pulping degrades wood by dissolving the lignin bonds holding the cellulose fibers together. Generally, this process involves the cooking/digesting of wood chips in aqueous chemical solutions at elevated temperatures and pressures. There are two major types of chemical pulping currently used in the U.S.: 1) kraft/soda pulping and 2) sulfite pulping. These processes differ primarily in the chemicals used for digesting. The specialty paper products rayon, viscose, acetate, and cellophane are made from dissolving pulp, a variant of standard kraft or sulfite chemical pulping processes.

Kraft pulping (or sulfate) processes produced approximately 83 percent of all US pulp tonnage during 2000 according to the American Forest and Paper Association (AF&PA, 2001). The success of the process and its widespread adoption are due to several factors. First, because the kraft cooking chemicals are selective in their attack on wood constituents, the pulps produced are notably stronger than those from other processes (i.e., Kraft is German for "strength"). The kraft process is also flexible, in so far as it is amenable to many different types of raw materials (i.e., hard or soft woods) and can tolerate contaminants frequently found in wood (e.g., resins). Lignin removal rates are high in the kraft process — up to 90 percent — allowing high levels of bleaching without pulp degradation. Finally, the chemicals used in kraft pulping are readily recovered within the process, making it very economical and reducing potential environmental releases (See *Chemical Recovery Systems* below).

The kraft process uses a sodium-based alkaline pulping solution (liquor) consisting of sodium sulfide (Na_2S) and sodium hydroxide ($NaOH$) in 10 percent solution. This liquor (white liquor) is mixed with the wood chips in a reaction vessel (digester). The output products are separated wood fibers (pulp) and a liquid that contains the dissolved lignin solids in a solution of reacted and unreacted pulping chemicals (black liquor). The black liquor undergoes a chemical recovery process (see *Chemical Recovery Systems*) to regenerate white liquor for the first pulping step. Overall, the kraft process converts approximately 50 percent of input furnish into pulp.

The kraft process evolved from the soda process. The soda process uses an alkaline liquor of only sodium hydroxide (NaOH). The kraft process has virtually replaced the soda process due to the economic benefits of chemical recovery and improved reaction rates (the soda process has a lower yield of pulp per pound of wood furnish than the kraft process).

Sulfite pulping was used for approximately two percent of U.S. pulp production in 2000 (AF&PA, 2001). Softwood is the predominant furnish used in sulfite pulping processes. However, only non-resinous species are generally pulped. The sulfite pulping process relies on acid solutions of sulfurous acid (H_2SO_3) and bisulfite ion (HSO_3^-) to degrade the lignin bonds between wood fibers.

Sulfite pulps have less color than kraft pulps and can be bleached more easily, but are not as strong. The efficiency and effectiveness of the sulfite process is also dependent on the type of wood furnish and the absence of bark. For these reasons, the use of sulfite pulping has declined in comparison to kraft pulping over time.

Semi-chemical pulping

Semi-chemical pulping comprised six percent of U.S. pulp production in 2000 (AF&PA, 2001). Semi-chemical pulp is often very stiff, making this process common in corrugated container manufacture. This process primarily uses hardwood as furnish.

The major process difference between chemical pulping and semi-chemical pulping is that semi-chemical pulping uses lower temperatures, more dilute cooking liquor or shorter cooking times, and mechanical disintegration for fiber separation. At most, the digestion step in the semi-chemical pulping process consists of heating pulp in sodium sulfite (Na_2SO_3) and sodium carbonate (Na_2CO_3) Other semi-chemical processes include the Permachem process and the two-stage vapor process. The yield of semi-chemical pulping ranges from 55 to 90 percent, depending on the process used, but pulp residual lignin content is also high so bleaching is more difficult.

Mechanical pulping

Mechanical pulping accounted for nine percent of U.S. pulp production in 2000 (AF&PA, 2001). Mechanically produced pulp is of low strength and quality. Such pulps are used principally for newsprint and other non-permanent paper goods. Mechanical pulping relies on physical pressure instead of chemicals to separate furnish fibers; however, chemicals are sometimes added at the various stages of refining. Processes include: 1) stone groundwood, 2) refiner mechanical, 3) thermo-mechanical, 4) chemi-mechanical, and 5) chemi-thermo-mechanical. The stone groundwood process simply involves mechanical grinding of wood in several high-energy refining systems. The refiner mechanical process involves refining wood chips at atmospheric pressure while the thermo-mechanical process uses steam and pressure to soften the chips before mechanical refining. In the chemi-mechanical process, chemicals can be added throughout the process to aid the mechanical refining. The chemi-thermo-mechanical process involves the treatment of chips with chemicals for softening followed by mechanical pulping under heat and pressure. Mechanical pulping typically results in high pulp yields, up to 95 percent when compared to chemical pulping yields of 45- 50 percent, but energy usage is also high. To offset its structural weakness, mechanical pulp is often blended with chemical pulp.

Secondary fiber pulping

Secondary fiber pulping accounted for 39 percent of domestic pulp production in 2000 (AF&PA, 2001). Nearly 200 mills rely exclusively on recovered paper for pulp furnish, and roughly 80 percent of U.S. paper mills use recovered paper in some way (AF&PA, 2000c). In addition, consumption of fiber from recovered paper is growing more than twice as fast as overall fiber consumption. Secondary fibers are usually presorted before they are sold to a pulp and paper mill. If not, secondary fibers are processed to remove contaminants before pulping occurs. Common contaminants consist of adhesives, coatings, polystyrene foam, dense plastic chips, polyethylene films, wet strength resins, and synthetic fibers. In some cases, contaminants of greater density than the desired secondary fiber are removed by centrifugal force while light contaminants are removed by flotation systems. Centri cleaners are also used to remove material less dense than fibers (wax and plastic particles) (AF&PA, 1995b).

Inks, another contaminant of secondary fibers, may be removed by heating a mixture of secondary fibers with surfactants. The removed inks are then dispersed in an aqueous media to prevent redeposition on the fibers. Continuous solvent extraction has also been used to recover fibers from paper and board coated with plastics and/or waxes.

Secondary fiber pulping is a relatively simple process. The most common pulper design consists of a large container filled with water, which is sometimes heated, and the recycled pulp. Pulping chemicals (e.g., sodium hydroxide, NaOH) are often added to promote dissolution of the paper or board matrix. The source fiber (corrugated containers, mill waste, etc.) is dropped into the pulper and mixed by a rotor. Debris and impurities are removed by two mechanisms: a ragger and a junker. The ragger withdraws strings, wires, and rags from the stock secondary fiber mixture. A typical ragger consists of a few "primer wires" that are rotated in the secondary fiber slurry. Debris accumulates on the primer wires, eventually forming a "debris rope" which is then removed. Heavier debris are separated from the mixture by centrifugal force and fall into a pocket on the side of the pulper. The junker consists of a grappling hook or elevator bucket. Heat, dissolution of chemical bonds, shear forces created by stirring and mixing, and grinding by mechanical equipment may serve to dissociate fibers and produce a pulp of desired consistency.

Contaminant removal processes depend on the type and source of secondary fiber to be pulped. Mill paper waste can be easily repulped with minimal contaminant removal. Recycled post-consumer newspaper, on the other hand, may require extensive contaminant removal, including deinking, prior to reuse. As noted in *Furnish Composition* above, secondary fiber typically is used in lower-quality applications such as multi-ply paperboard or corrugating paper.

III.A.2. Pulp Processing

After pulp production, pulp processing removes impurities, such as uncooked chips, and recycles any residual cooking liquor via the washing process (Figure 7). Pulps are processed in a wide variety of ways, depending on the method that generated them (e.g., chemical, semi-chemical). Some pulp processing steps that remove pulp impurities include screening, defibering, and deknotting. Pulp may also be thickened by removing a portion of the water. At additional cost, pulp may be blended to ensure product uniformity. If pulp is to be stored for long periods of time, drying steps are necessary to prevent fungal or bacterial growth.

Residual spent cooking liquor from chemical pulping is washed from the pulp using brown stock washers. Efficient washing is critical to maximize return of cooking liquor to chemical recovery (see *Chemical Recovery Systems* below) and to minimize carryover of cooking liquor (known as brown stock washing loss) into the bleach plant, because excess cooking liquor increases consumption of bleaching chemicals. Specifically, the dissolved organic compounds (lignins and hemicelluloses) contained in the liquor will bind to bleaching chemicals and thus increase bleach chemical consumption. In addition, these organic compounds function as precursors to chlorinated organic compounds (e.g., dioxins, furans), increasing the probability of their formation. The most common washing technology is rotary vacuum washing, carried out sequentially in two or four washing units. Other washing technologies include diffusion washers, rotary pressure washers, horizontal belt filters, wash presses, and dilution/extraction washers.

Pulp screening, removes remaining oversized particles such as bark fragments, oversized chips, and uncooked chips. In *open* screen rooms, wastewater from the screening process goes to wastewater treatment prior to discharge. In *closed loop* screen rooms, wastewater from the process is reused in other pulping operations and ultimately enters the mill's chemical recovery system. Centrifugal cleaning (also known as liquid cyclone, hydrocyclone, or centricleaning) is used after screening to remove relatively dense contaminants such as sand and dirt. Rejects from the screening process are either repulped or disposed of as solid waste.

Chemical Recovery Systems

The chemical recovery system is a complex part of a chemical pulp and paper mill and is subject to a variety of environmental regulations. Chemical recovery is a crucial component of the chemical pulping process: it recovers process chemicals from the spent cooking liquor for reuse. The chemical recovery process has important financial and environmental benefits for pulp and paper mills. Economic benefits include savings on chemical purchase costs due to regeneration rates of process chemicals approaching 98 percent, and energy generation from pulp residue burned in a recovery furnace (Smook, 1992). Environmental benefits include the recycle of process chemicals and lack of resultant discharges to the environment.

The kraft, sulfite, and semi-chemical pulping processes all use chemical recovery systems of some form; however, the actual chemical processes at work differ markedly. Due to its widespread usage, only the kraft chemical recovery system will be covered in depth in this document. Sulfite chemical recovery systems are discussed briefly at the end of this section.

Kraft Chemical Recovery Systems

Although newer technologies are always under development, the basic kraft chemical recovery process has not been fundamentally changed since its patent issue in 1884. The stepwise progression of chemical reactions has been refined; for example, black liquor gasification processes are now in use in an experimental phase. The precise details of the chemical processes at work in the chemical recovery process can be found in Smook, *Handbook for Pulp and Paper Technologists,* 2nd Edition, 1992 and will not be discussed here. The kraft chemical recovery process consists of the following general steps:

Black liquor concentration

Residual weak black liquor from the pulping process is concentrated by evaporation to form "strong black liquor." After brown stock washing in the pulping process, the concentration of solids in the weak black liquor is approximately 15 percent; after the evaporation process, solids concentration can range from 60 - 80 percent. In some older facilities, the liquor then undergoes oxidation for odor reduction. The oxidation step is necessary to reduce odor created when hydrogen sulfide is stripped from the liquor during the subsequent recovery boiler burning process. Almost all recovery furnaces installed since 1968 have non-contact evaporation processes that avoid these problems, so oxidation processes are not usually seen in mills with modern recovery furnaces. Common modern evaporator types include multiple effect evaporators as well as a variety of supplemental evaporators. Odor problems with the kraft process have been the subject of control measures (See Section III.B. Raw Material Inputs and Pollution Outputs in the Production Line for more information).

Recovery boiler

The strong black liquor from the evaporators is burned in a recovery boiler. In this crucial step in the overall kraft chemical recovery process, organic solids are burned for energy and the process chemicals are removed from the mixture in molten form. Molten inorganic process chemicals (smelt) flow through the perforated floor of the boiler to water-cooled spouts and dissolving tanks for recovery in the recausticizing step.

Energy generation from the recovery boiler is often insufficient for total plant needs, however, so facilities augment recovery boilers with fossil-fuel-fired and wood-waste-fired boilers (hogged fuel) to generate steam and often electricity. Industry-wide, the utilization of pulp wastes, bark, and other papermaking residues supplies 58 percent of the energy requirements of pulp and paper companies (AF&PA, 1999) (see III.A.3. Energy Generation for more information).

Recausticizating

Smelt is recausticized to remove impurities left over from the furnace and to convert sodium carbonate (Na_2CO_3) into active sodium hydroxide (NaOH) and sodium sulfide (Na_2S). The recausticization procedure begins with the mixing of smelt with "weak" liquor to form green liquor, named for its characteristic color. Contaminant solids, called dregs, are removed from the green liquor, which is mixed with lime (CaO). After the lime mixing step, the mixture, now called white liquor due to its new coloring, is processed to remove a layer of lime mud ($CaCO_3$) that has precipitated. The primary chemicals recovered are caustic (NaOH) and sodium sulfide (Na_2S). The remaining white liquor is then used in the pulp cooking process. The lime mud is treated to regenerate lime in the calcining process.

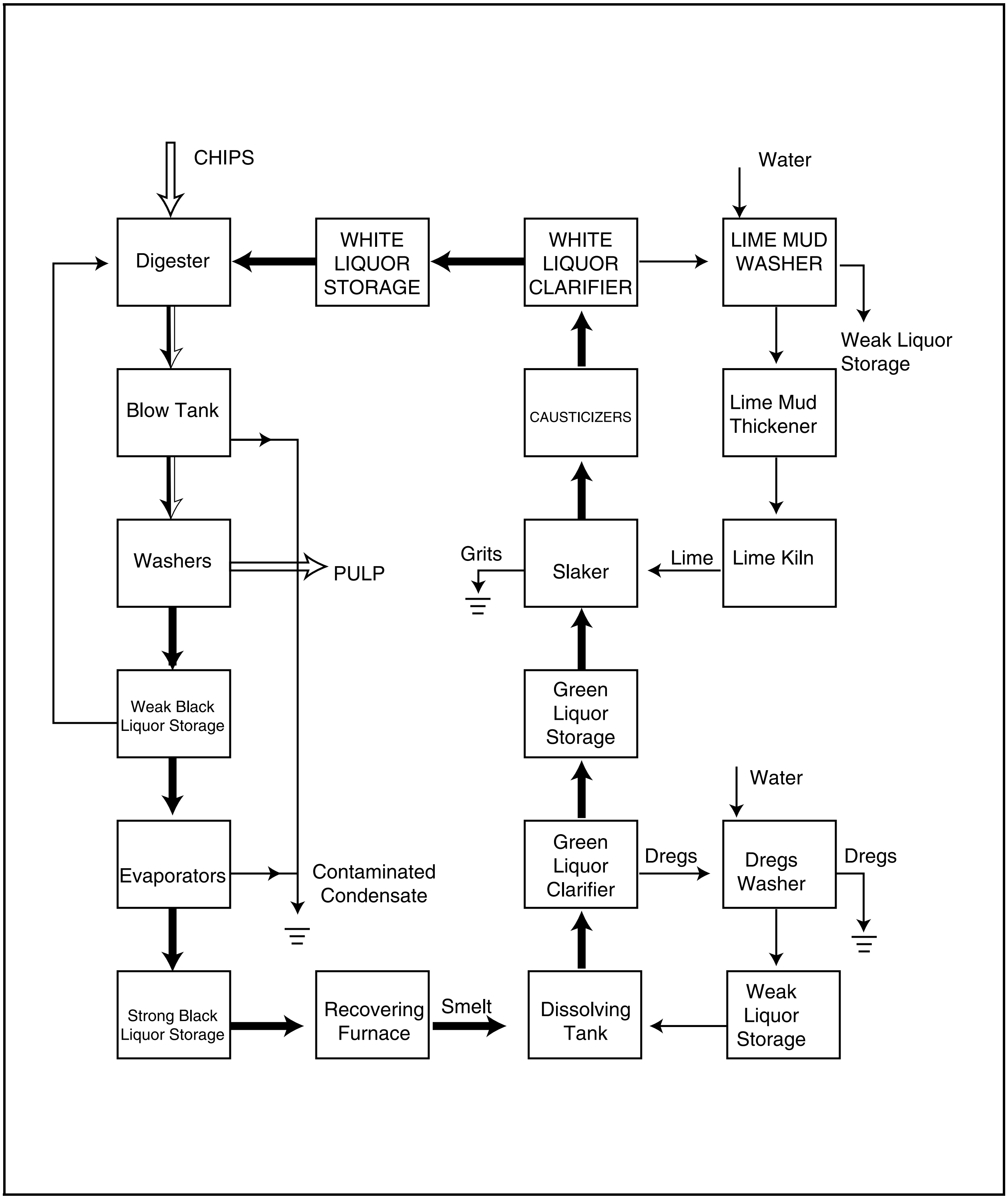
Calcining

In the calcining process, the lime mud removed from the white liquor is burned to regenerate lime for use in the lime mixing step. The vast majority of mills use lime kilns for this process, although a few mills use fluidized bed systems in which the reactants are suspended by upward-blowing air.

Sulfite Chemical Recovery Systems

There are a variety of sulfite chemical pulping recovery systems in use today. Heat and sulfur can be recovered from all liquors generated, however the base chemical can only be recovered from magnesium and sodium base processes (see Smook, 1992 for more information).

Figure 7: The Kraft Pulping Process (with Chemical Recovery)



Source: Smook, 1992.

III.A.3. Bleaching

Bleaching is defined as any process that chemically alters pulp to increase its brightness. Bleached pulps create papers that are whiter, brighter, softer, and more absorbent than unbleached pulps. Bleached pulps are used for products where high purity is required and yellowing (or color reversion) is not desired (e.g. printing and wrapping papers, food contact papers). Unbleached pulp is typically used to produce boxboard, linerboard, and grocery bags. Of the approximately 72 million tons of pulp production capacity in the United States in 2000, about 50 percent is for bleached pulp (AF&PA, 2001).

Any type of pulp may be bleached, but the type(s) of fiber furnish and pulping processes used, as well as the desired qualities and end use of the final product, greatly affect the type and degree of pulp bleaching possible. Printing and writing papers comprise approximately 60 percent of bleached paper production. The lignin content of a pulp is the major determinant of its bleaching potential. Pulps with high lignin content (e.g., mechanical or semi-chemical) are difficult to bleach fully and require heavy chemical inputs. Excessive bleaching of mechanical and semi-chemical pulps results in loss of pulp yield due to fiber destruction. Chemical pulps can be bleached to a greater extent due to their low (10 percent) lignin content.

For more information, the *Summary of Technologies for the Control and Reduction of Chlorinated Organics from the Bleached Chemical Pulping Subcategories of the Pulp and Paper Industry*, 1990 from the Office of Water Regulations and Standards is recommended. Typical bleaching processes for each pulp type are detailed below.

Chemical pulp bleaching has undergone significant process changes since approximately 1990. At that time, nearly every chemical pulp mill that used bleaching incorporated elemental chlorine (Cl_2) into some of its processes. Because of environmental and health concerns about dioxins, U.S. pulp mills now use elemental chlorine free (ECF) and total chlorine free (TCF) bleaching technologies. The most common types of ECF and TCF are shown in Table 8; the difference between ECF and TCF is that ECF may include chlorine dioxide (ClO_2) and hypochlorite (HClO, NaOCl, and $Ca(OCl)_2$) based technologies. In 2001, ECF technologies were used for about 95 percent of bleached pulp production, TCF technologies were used for about 1 percent of bleached pulp production, and elemental chlorine was used for about 4 percent of production (AET, 2002).

Table 8: Common Chemicals Used in Elemental Chlorine Free (ECF) and Total Chlorine Free (TCF) Bleaching Processes

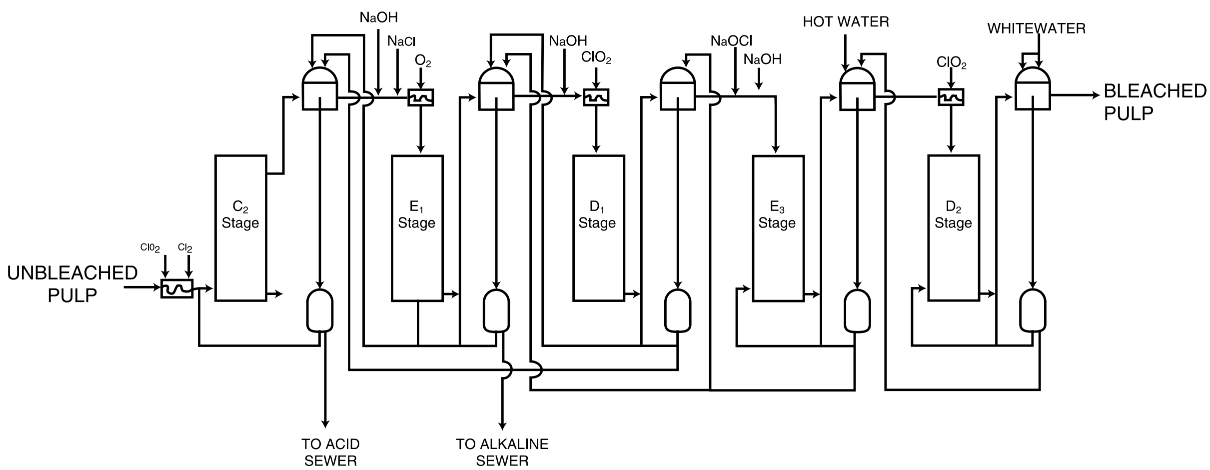
Bleaching Chemical	Chemical Formula	ECF/TCF
Sodium Hydroxide	$NaOH$	ECF and TCF
Chlorine Dioxide	ClO_2	ECF
Hypochlorite	$HClO$, $NaOCl$, $Ca(OCl)_2$	ECF
Oxygen	O_2	ECF and TCF
Ozone	O_3	ECF and TCF
Hydrogen Peroxide	H_2O_2	ECF and TCF
Sulfur Dioxide	SO_2	ECF and TCF
Sulfuric Acid	H_2SO_4	ECF and TCF

Source: U.S. EPA, 2001.

Chemical pulp is bleached in traditional bleach plants (see Figure 8) where the pulp is processed through three to five stages of chemical bleaching and water washing. The number of cycles is dependent on the whiteness desired, the brightness of initial stock pulp, and plant design.

Bleaching stages generally alternate between acid and alkaline conditions. Chemical reactions with lignin during the acid stage of the bleaching process increase the whiteness of the pulp. The alkaline extraction stages dissolve the lignin/acid reaction products. At the washing stage, both solutions and reaction products are removed. Chemicals used to perform the bleaching process must have high lignin reactivity and selectivity to be efficient. Typically, 4-8 percent of pulp is lost due to bleaching agent reactions with the wood constituents cellulose and hemicellulose, but, these losses can be as high as 18 percent.

Figure 8: Typical Bleach Plant



Source: U.S. EPA, 1993a.

Semi-chemical pulps are typically bleached with hydrogen peroxide (H_2O_2) in a bleach tower.

Mechanical pulps are bleached with hydrogen peroxide (H_2O_2) and/or sodium hydrosulfite (Na_2SO_3). Bleaching chemicals are either applied without separate equipment during the pulp processing stage (i.e., in-line bleaching), or in bleaching towers. Full bleaching of mechanical pulps is generally not practical due to bleaching chemical cost and the negative impact on pulp yield.

Deinked secondary fibers are usually bleached in a bleach tower, but may be bleached during the repulping process. Bleach chemicals may be added directly into the pulper. The following are examples of chemicals used to bleach deinked secondary fibers: hypochlorite (HClO, NaOCl, $Ca(OCl)_2$), hydrogen peroxide (H_2O_2), and hydrosulphite ($Na_2S_2O_4$).

III.A.4. Stock Preparation

At this final stage, the pulp is processed into the stock used for paper manufacture. Market pulp, which is to be shipped off-site to paper or paperboard mills, is simply dried and baled during this step. Processing of pulp in integrated mills includes pulp blending specific to the desired paper product desired, dispersion in water, beating and refining to add density and strength, and addition of any necessary wet additives. Wet additives are used to create paper products with special properties or to facilitate the papermaking process. Wet additives include resins and waxes for water repellency, fillers such as clays, silicas, talc, inorganic/organic dyes for coloring, and certain inorganic chemicals (calcium sulfate, zinc sulfide, and titanium dioxide) for improved texture, print quality, opacity, and brightness.

III.A.5. Processes in Paper Manufacture

The paper and paperboard making process consists of the following general steps:

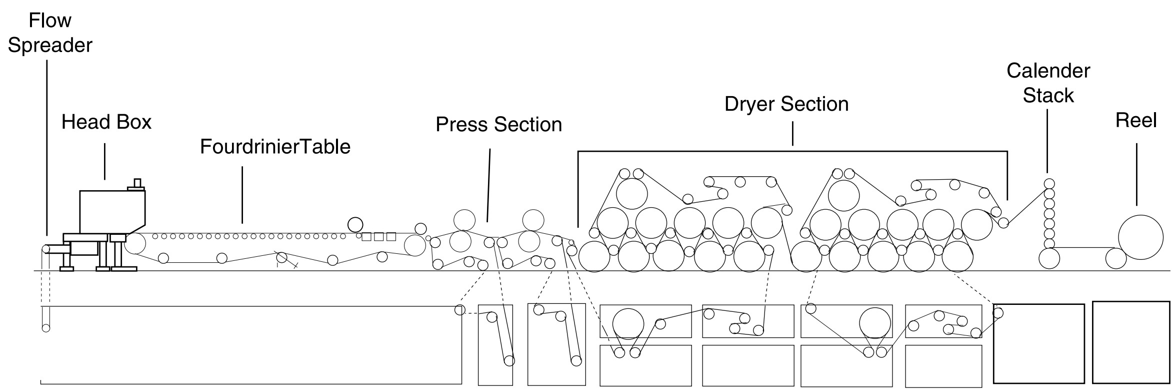
Table 9: Paper and Paperboard Making Process

Sequential Process	Description
Wet End Operations	Formation of paper sheet from wet pulp
Dry End Operations	Drying of paper product, application of surface treatments, spooling for storage

Wet End Operations

The processed pulp is converted into a paper product via a paper production machine, the most common of which is the Fourdrinier paper machine (see Figure 9). In the Fourdrinier system, the pulp slurry is deposited on a moving wire belt that carries it through the first stages of the process. Water is removed by gravity, vacuum chambers, and vacuum rolls. This waste water is recycled to the slurry deposition step of the process due to its high fiber content. The continuous sheet is then pressed between a series of rollers to remove more water and compress the fibers.

Figure 9: Fourdrinier Paper Machine



Source: U.S. EPA, 1993a.

Dry End Operations

After pressing, the sheet enters a drying section, where the paper fibers begin to bond together as steam heated rollers compress the sheets. In the calender process the sheet is pressed between heavy rolls to reduce paper thickness and produce a smooth surface. Coatings can be applied to the paper at this point to improve gloss, color, printing detail, and brilliance. Lighter coatings are applied on-machine, while heavy coatings are performed off-machine. The paper product is then spooled for storage.

III.A.6. Energy Generation

Pulp and paper mill energy generation is provided in part from the burning of liquor waste solids in the recovery boiler, but other energy sources are needed to make up the remainder of mill energy needs. Over the last 25 years, the pulp and paper industry has changed its energy generation methods from fossil fuels to a greater utilization of processes or process wastes. The increase in use of wood wastes from the wood handling and chipping processes depicted in Table 10 below is one example of this industry-wide movement. During the 1972-1999 period, the proportion of total industry power generation from the combination of woodroom wastes, spent liquor solids, and other self-generation methods increased from about 41 percent to about 58 percent, while coal, fuel oil and natural gas use decreased from about 54 percent to about 36 percent.

Power boilers at pulp and paper mills are sources of particulate emissions, sulfur dioxide ($SO_{2)}$, and nitrogen oxides (NO_x). Pollutants emitted from chemical recovery boilers include SO_2, and total reduced sulfur compounds (TRS).

Table 10: Estimated Energy Sources for the U.S. Pulp and Paper Industry

Energy Source	1972[a]	1979[a]	1990[a]	1999[b]
Purchased steam	5.4%	6.7%	7.3%	1.5%
Coal	9.8%	9.1%	13.7%	12.5%
Fuel oil	22.3%	19.1%	6.4%	6.3%
Natural gas	21.5%	17.8%	16.4%	17.6%
Other purchased energy	-	-	-	6.7%
Waste wood and wood chips (Hogged fuel) and bark	6.6%	9.2%	15.4%	13.5%
Spent liquor solids	33.7%	37.3%	39.4%	40.3%
Other self-generated power	0.6%	0.8%	1.2%	1.6%

Sources: [a]American Paper Institute Data as presented in Smook, 1992.
[b]AF&PA, 2001.

III.B. Raw Material Inputs and Pollution Outputs in the Production Line

Pulp and paper mills use and generate materials that may be harmful to the air, water, and land: pulp and paper processes generate large volumes of wastewaters which might adversely affect freshwater or marine ecosystems, residual wastes from wastewater treatment processes may contribute to existing local and regional disposal problems, and air emissions from pulping processes and power generation facilities may release odors, particulates, or other pollutants. Major sources of pollutant releases in pulp and paper manufacture are at the pulping and bleaching stages respectively. As such, non-integrated mills (i.e., those mills without pulping facilities on-site) are not significant environmental concerns when compared to integrated mills or pulp mills.

Water

The pulp and paper industry is the largest industrial process water user in the U.S. (U.S. Department of Commerce, 2000). In 2000, a typical pulp and paper mill used 4,000-12,000 gallons of water per ton of pulp produced (Pulp and Paper, 2001). General water pollution concerns for pulp and paper mills are effluent solids, biochemical oxygen demand, and color. Toxicity concerns historically occurred from the potential presence of chlorinated organic compounds such as dioxins, furans, and others (collectively referred to as adsorbable organic halides, or AOX) in wastewaters after the chlorination/extraction sequence. With the substitution of chlorine dioxide for chlorine, effluent loads of the chlorinated compounds decreased dramatically.

Due to the large volumes of water used in pulp and paper processes, virtually all U.S. mills have primary and secondary wastewater treatment systems installed to remove particulate and biochemical oxygen demand (BOD) produced in the manufacturing processes. These systems also provide significant removal (e.g., 30-70 percent) of other important parameters such as AOX and chemical oxygen demand (COD).

The major sources of effluent pollutants in a pulp and paper mill are presented in Table 11.

Table 11: Potential Water Pollutants From Pulp and Paper Processes

Source	Effluent characteristics
Water used in wood handling/debarking and chip washing	Solids, BOD, color
Chip digester and liquor evaporator condensate	Concentrated BOD, reduced sulfur compounds
"White waters" from pulp screening, thickening, and cleaning	Large volume of water with suspended solids, can have significant BOD
Bleach plant washer filtrates	BOD, color, chlorinated organic compounds
Paper machinewater flows	Solids
Fiber and liquor spills	Solids, BOD, color

Source: Smook, 1992.

Wood processing operations in pulp mills often use water for a variety of purposes. The resulting wastewaters contain BOD, suspended solids, and some color. The condensates from chip digesters and chemical recovery evaporators are sources of BOD and reduced sulfur compounds. Wastewaters containing BOD, color, and suspended solids may be generated from pulp screening operations in mills using "atmospheric" systems, though most mills have modern pressure screens that virtually eliminate such wastewaters. Kraft bleaching generates large volumes of wastewater containing BOD, suspended solids, color, and chlorinated organic compounds. From paper machines, excess white water (named for its characteristic color) contains suspended solids and BOD. Fiber and liquor spills can also be a source of mill effluent. Typically, spills are captured and pumped to holding areas to reduce chemical usage through spill reuse and to avoid loadings on facility wastewater treatment systems.

Wastewater treatment systems can be a significant source of cross-media pollutant transfer. For example, waterborne particulate and some chlorinated compounds settle or absorb onto treatment sludge and other compounds may volatilize during the wastewater treatment process.

Air

The following table is an overview of the major types and sources of air pollutant releases from various pulp and paper processes:

Table 12: Common Air Pollutants From Pulp and Paper Processes

Source	Type
Kraft recovery furnace	Fine particulates, nitrogen oxides
Fly ash from hog fuel and coal-fired burners	Coarse particulates
Sulfite mill operations	Sulfur oxides, ammonia
Kraft pulping and recovery processes	Reduced sulfur gases
Chip digesters and liquor evaporation	Volatile organic compounds
Pulp drying (non-integrated mills)	Volatile organic compounds
All combustion processes	Nitrogen oxides

Source: Smook, 1992.

Water vapors are the most visible air emission from a pulp and paper mill, but are not usually regulated unless they are a significant obscurement or climate modifier.

Pulp and paper mill power boilers are generic pulp and paper mill sources of air pollutants such as particulates and nitrogen oxides. Chip digesters and chemical recovery evaporators are the most concentrated sources of volatile organic compounds. The chemical recovery furnace is a source of fine particulate emissions and sulfur oxides. In the kraft process, sulfur oxides are a minor issue in comparison to the odor problems created by four reduced sulfur gasses, called together total reduced sulfur (TRS): hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide. The TRS emissions are primarily released from wood chip digestion, black liquor evaporation, and chemical recovery boiler processes. TRS compounds create odor nuisance problems at lower concentrations than sulfur oxides: odor thresholds for TRS compounds are approximately 1,000 times lower than that for sulfur dioxide. Humans can detect some TRS compounds in the air as a "rotten egg" odor at as little as one part per billion.

Pulp and paper mills have made significant investments in pollution control technologies and processes. According to industry sources, the pulp and paper industry spent more than $1 billion per year from 1991-1997 on environmental capital expenditures. In 1991 and 1992, this represented 20 percent of total capital expenditures (AF&PA, 1994). Chemical recovery and recycling systems in the chemical pulping process significantly reduce pollutant outputs while providing substantial economic return due to recovery of process chemicals. Chemical recovery is necessary for the basic economic viability of the kraft process. According to EPA sources, all kraft pulp mills worldwide have chemical recovery systems in place. Some sulfite mills, however, still do not have recovery systems in place. Scrubber system particulate "baghouses" or electrostatic precipitators (ESPs) are often mill air pollution control components.

Residual Wastes

The significant residual waste streams from pulp and paper mills include wastewater treatment sludges, lime mud, lime slaker grits, green liquor dregs, boiler and furnace ash, scrubber sludges, and wood processing residuals. Because of the tendency for chlorinated organic compounds to partition from effluent to solids, wastewater treatment sludge is a significant environmental concern for the pulp and paper industry.

Wastewater treatment sludge is the largest volume residual waste stream generated by the pulp and paper industry. Sludge generation rates vary widely among mills. For example, bleached kraft mills surveyed as part of EPA's 104-Mill Study reported sludge generation that ranged from 14 to 140 kg of sludge per ton of pulp (U.S. EPA, 1988). Total sludge generation for these 104 mills was 2.5 million dry metric tons per year, or an average of approximately 26,000 dry metric tons per year per plant. Pulpmaking operations are responsible for the bulk of sludge wastes, although treatment of papermaking effluents also generates significant sludge volumes. For the majority of pulp and integrated mills that operate their own wastewater treatment systems, sludges are generated onsite. A small number of pulp mills, and a much larger proportion of papermaking establishments, discharge effluents to publicly-owned wastewater treatment works (POTWs).

Potential environmental hazards from wastewater sludges are associated with trace constituents (e.g., chlorinated organic compounds) that partition from the effluent into the sludge. It should be noted, however, that recent trends away from elemental chlorine bleaching have reduced these hazards. A continuing concern is the very high pH (>12.5) of most residual wastes. When these wastes are disposed of in an aqueous form, they may meet the RCRA definition of a corrosive hazardous waste (U.S. EPA, 2002).

Landfill and surface impoundment disposal are most often used for wastewater treatment sludge, but a significant number of mills dispose of sludge through land application, conversion to sludge-derived products (e.g., compost and animal bedding), or combustion for energy recovery (AF&PA, 2002).

Process Inputs and Pollutant Outputs

Kraft chemical pulping and chlorine-based (e.g., hypochlorite or chlorine dioxide) bleaching are both commonly used and may generate significant pollutant outputs. Kraft pulping processes produced approximately 83 percent of total US pulp tonnage during 1998 according to the American Forest and Paper Association (AF&PA, 1999). Roughly 60 percent of this amount is bleached in some manner.

Pollutant outputs from mechanical, semi-chemical, and secondary fiber pulping are small when compared to kraft chemical pulping. In the pulp and paper industry, the kraft pulping process is the most significant source of air pollutants. The following table and figures (Table 13 and Figures 10 and 11) illustrate the process inputs and pollutant outputs for a pulp and paper mill using kraft chemical pulping and chlorine-based bleaching. The process outlined below produces a large portion of U.S. pulp.

Table 13 presents the process steps, material inputs, and major pollutant outputs (by media) of a kraft pulp mill practicing traditional chlorine bleaching. The following resources are recommended for pollutant production data (e.g., pounds of BOD per ton of pulp produced) for those pollutants presented in Table 13:

- *Pollution Prevention Technologies for the Bleached Kraft Segment of the U.S. Pulp and Paper Industry.* August 1993. (EPA-600-R-93-110)

- *Development Document for Proposed Effluent Limitations Guidelines and standards for the Pulp, Paper, and Paperboard Point Source Category*. October 1993. (EPA-821-R-93-019)

- *Pulp, Paper and Paperboard Industry - Background Information for Proposed Air Emission Standards: Manufacturing Processes at Kraft, Sulfite, Soda, and Semi-Chemical Mills, NESHAP.* October 1993. (EPA-453-R-93-050a)

Figure 10 is a process flow diagram of the kraft process, illustrating chemical pulping, power recovery, and chemical recovery process inputs and outputs. Figure 11 is a schematic of characteristic air emission sources from a kraft mill.

Table 13: Kraft Chemical Pulped Bleached Paper Production

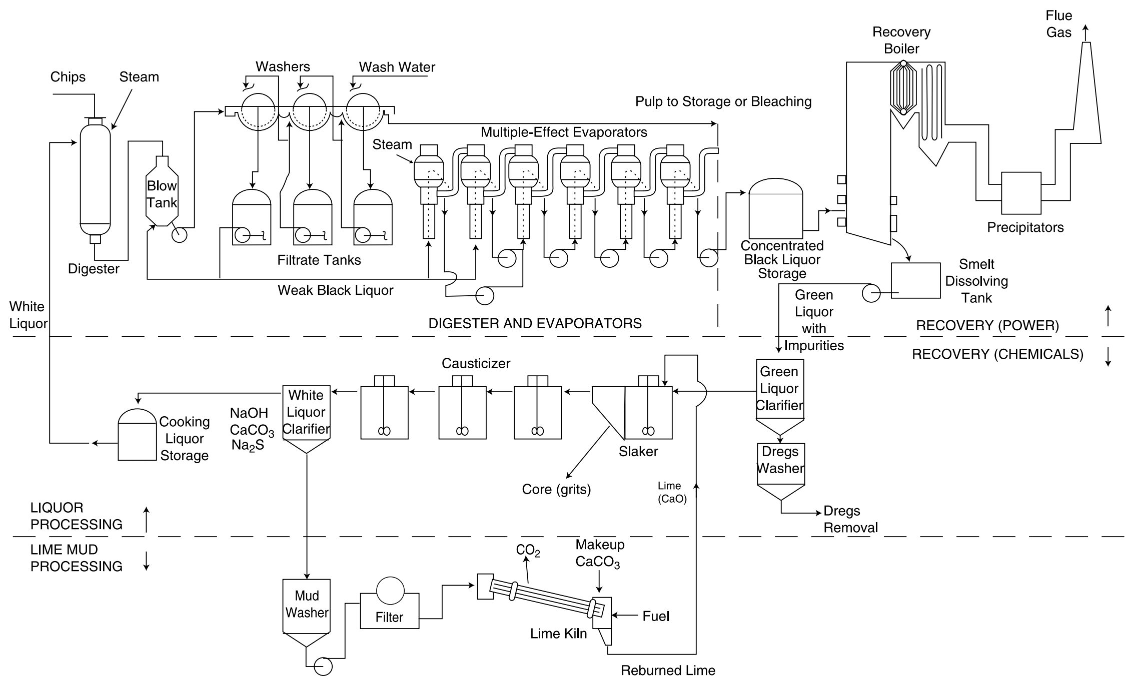
Process Step	Material Inputs	Process Outputs	Major Pollutant Outputs[a]	Pollutant Media
Fiber Furnish Preparation	Wood logs Chips Sawdust	Furnish chips	dirt, grit, fiber, bark	Solid
			BOD	Water
			TSS	
Chemical Pulping Kraft process	Furnish chips	Black liquor (to chemical recovery system), pulp (to bleaching/ processing)	resins, fatty acids	Solid
			color	Water
			BOD	
			COD	
			AOX	
			VOCs [terpenes, alcohols, phenols, methanol, acetone, chloroform, methyl ethyl ketone (MEK)]	
			VOCs (terpenes, alcohols, phenols, methanol, acetone, chloroform, MEK)	Air
	Cooking chemicals: sodium sulfide (Na_2S), NaOH, white liquor (from chemical recovery)		reduced sulfur compounds (TRS)	
			organo-chlorine compounds (e.g., 3,4,5- trichloroguaiacol)	
Bleaching[b]	Chemical pulp	Bleached pulp	dissolved lignin and carbohydrates	Water
			color	
			COD	
			AOX	
			inorganic chlorine compounds (e.g., chlorate (ClO_3^-))[c]	
	Hypochlorite (HClO, NaOCl, $Ca(OCl)_2$) Chlorine dioxide (ClO_2)		VOCs (acetone, methylene chloride, chloroform, MEK, chloromethane, trichloroethane)	Air / Water
Papermaking	Additives, Bleached/ Unbleached pulp	Paper/paperboard product	particulate wastes	Water
			organic compounds	
			inorganic dyes	
			COD	
			acetone	

Table 13: Kraft Chemical Pulped Bleached Paper Production (continued)

Process Step	Material Inputs	Process Outputs	Major Pollutant Outputs[a]	Pollutant Media
Wastewater Treatment Facilities	Process wastewaters	Treated effluent	sludge	Solid
			VOCs (terpenes, alcohols, phenols, methanol, acetone, chloroform, MEK)	Air
			BOD	Water
			TSS	
			COD	
			color	
			chlorophenolics	
			VOCs (terpenes, alcohols, phenols, methanol, acetone, chloroform, MEK)	
Power Boiler	Coal, Wood, Unused furnish	Energy	bottom ash: incombustible fibers	Solid
			SO_2, NO_x, fly ash, coarse particulates	Air
Chemical Recovery System				
Evaporators	Black liquor	Strong black liquor	evaporator noncondensibles (TRS, volatile organic compounds: alcohols, terpenes, phenols)	Air
			evaporator condensates (BOD, suspended solids)	Water
Recovery Furnace	Strong black liquor	Smelt	fine particulates, TRS, SO_2, NO_x	Air
		Energy		
Recausticizing	Smelt	Regenerated white liquor	dregs	Solids
		Lime mud	waste mud solids	Water, Solid
		Slaker grits	solids	Solid
Calcining (Lime Kiln)	Lime mud	Lime	fine and coarse particulates	Air

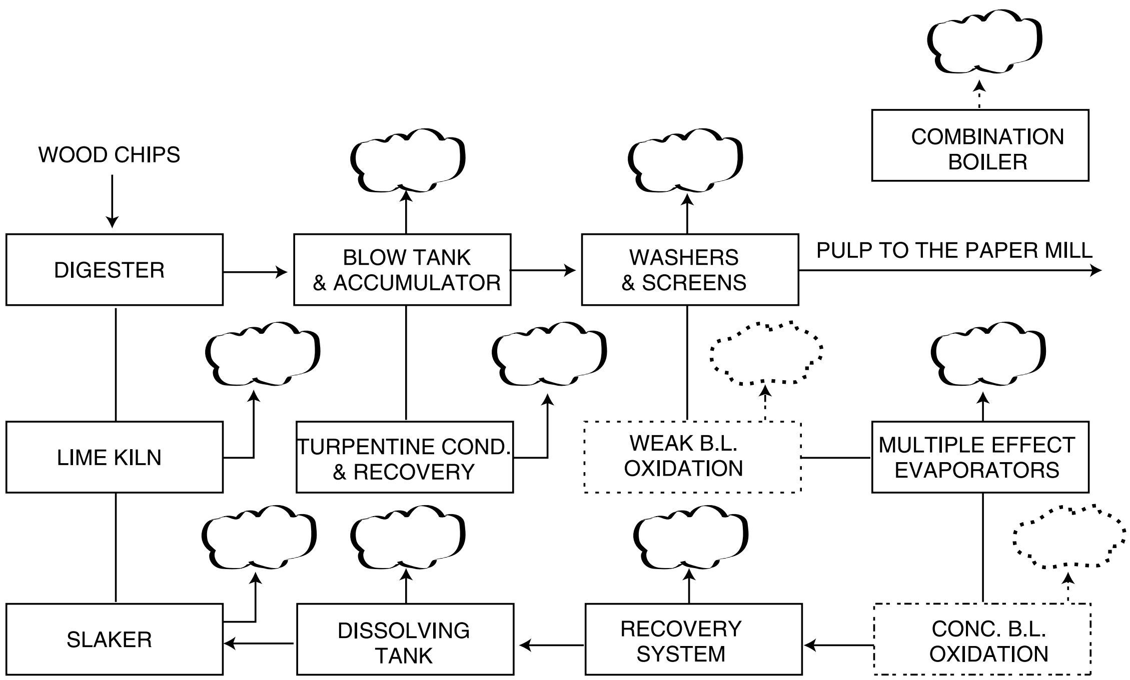
[a] Pollutant outputs may differ significantly based on mill processes and material inputs (e.g., wood chip resin content).
[b] Pollutant list based on Elemental Chlorine Free (ECF) bleaching technologies.
[c] Chlorate only significantly produced in mills with high rates of chlorine dioxide use.
Sources: EPA, 1993a; EPA, 1993b; and EPA, 1993c.

Figure 10: Kraft Process Flow Diagram



Source: Smook, 1992.

Figure 11: Air Pollutant Output from Kraft Process



Source: Smook, 1992.