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Proceedings

INTERNATIONAL SYMPOSIUM ON
POLLUTION PREVENTION IN THE MANUFACTURE OF PULP AND PAPER
~ OPPORTUNITIES & BARRIERS ~

August 18–20, 1992 • Washington, D.C.

Organized by the
Office of Pollution Prevention and Toxics

for the
U.S. Environmental Protection Agency
Pulp and Paper Cluster

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Proceedings

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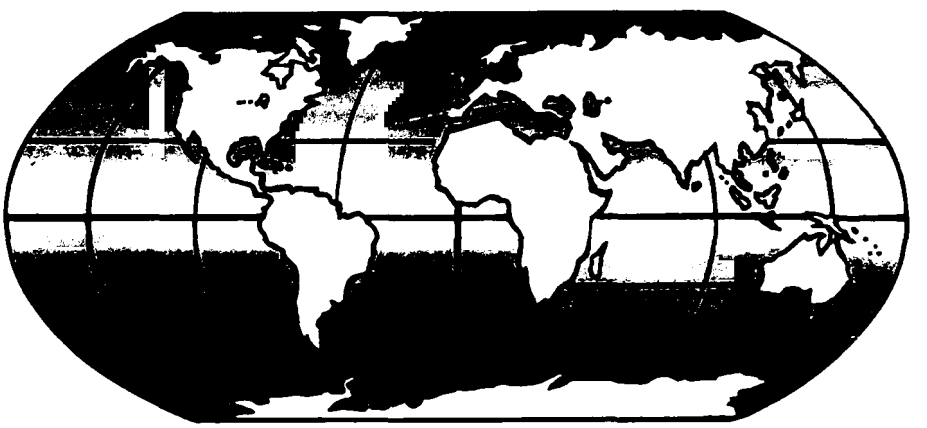
POLLUTION PREVENTION IN THE MANUFACTURE OF PULP AND PAPER
~ OPPORTUNITIES & BARRIERS ~



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Foreword

These proceedings document the presentations at the International Symposium on Pollution Prevention in the Manufacture of Pulp and Paper — Opportunities and Barriers. This symposium, held August 18-20, 1992, in Washington, D.C., was sponsored by the U.S. Environmental Protection Agency's (EPA's) Pulp and Paper Cluster. Comprised of high-level EPA personnel, the cluster is working to identify areas of concern in the pulp and paper industry and to coordinate Agency efforts to reduce pollution associated with the industry.

This symposium provided an opportunity for the international community to share information on factors affecting the adoption of pollution prevention practices in the pulp and paper industry. The broad range of perspectives of the panelists resulted in exciting and informative discussions regarding alternative pulping and bleaching technologies; trade-offs associated with the use of alternative technologies, including emissions, paper performance, and cost; government activities related to pulping and bleaching technologies; and industry activities related to evolving product performance specifications and customer demand for environmentally sound paper. Further details about these issues can be found in these proceedings.

The enthusiasm and personal experiences of the panelists and participants were a key to the symposium's success. Participants included pulp and paper manufacturers, paper converters, nonprofit organizations, government agencies, publishers, printers, and other wholesale and retail paper consumers. It is EPA's hope that this symposium was the first of many forums that will lead to more effective pollution prevention policies and programs within the pulp and paper industry.

These proceedings contain the text of the presentations, transcriptions of the question and answer sessions, the names and addresses of registered participants, and indices of the presenters and writers. The index of presenters includes brief biographical profiles of each. We hope that these proceedings will be a valuable reference tool.

U.S. EPA Pulp and Paper Cluster

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Tuesday, August 18, 1992

OVERVIEW OF EXISTING AND EMERGING TECHNOLOGIES

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Welcoming Remarks

Mark Greenwood
Director, Office of Pollution Prevention and Toxics
U.S. Environmental Protection Agency
Washington, D.C.

I would like to welcome everyone to the *International Symposium on Pollution Prevention in the Manufacture of Pulp and Paper: Opportunities and Barriers.* A summer meeting in Washington, D.C., guarantees that there will be no "sunshine patriots" here, but only people with interest in and great expertise on the topics to be presented.

Those of us from the U.S. Environmental Protection Agency (EPA) look forward to this symposium, because it provides an opportunity to hear from a wide range of experts who are seldom gathered together. There have been many technical conferences held by and for the international pulp and paper industry, but to my knowledge few have focused on the issues that relate to pollution prevention, and fewer still have given equal weight to considering the technological and institutional issues involved.

A conference like this one is particularly important because so few other industries face as much controversy when environmental performance is discussed. It is difficult to make a fair assessment of what is going on in the pulp and paper industry, and what manufacturers are capable of doing, because the industry is often faced with a barrage of conflicting information and opinions from all sides of the spectrum. This is clearly an area in which much useful information remains to be shared. Information is nobody's enemy.

Our hope for this symposium is that it will form a strong basis for common ground among industry, environmentalists, and government. Another conference goal is to focus on pollution prevention opportunities, without dwelling too much on the issue of risk.

It is my pleasure to introduce the first speakers. The first speaker, Linda Fisher, is the assistant administrator for the Office of Prevention, Pesticides, and Toxic Substances. She has served in that position for three years, and has brought many changes to her program area. She has been very much a leader in forging the link between the concept of pollution prevention and the management of toxic chemicals.

Our second speaker, Martha Prothro, is also a leader in the pollution prevention area. She has served for many years in EPA's Office of Water, and she is well-known for her thorough understanding of this industry. She is also known for her strong leadership on the regulatory issues that face the industry. It is no surprise that she chairs the Pulp and Paper Cluster, the interagency workgroup that coordinates EPA policy for the industry.

Compliance Is a Good Start, Prevention Is the Next Step

Linda Fisher
Assistant Administrator
Office of Prevention, Pesticides, and Toxic Substances
U.S. Environmental Protection Agency
Washington, D.C.

When we originally planned this symposium, peace and peace talks were breaking out all over. Even Palestine Liberation Organization leader Yasser Arafat had agreed to meet his lifelong adversaries at the negotiating table. So it seemed like a good idea, perhaps even a challenge, to bring industry, environmentalists, community leaders, and different levels of government together to talk about opportunities for and barriers to pollution prevention in the pulp and paper industry.

To add to the challenge that we were setting, we decided to hold the conference in August in Washington during the Republican National Convention. I think only a pro-choice plank in the Republican platform would have been more difficult to pull off. As symposium participants, you are to be commended for your willingness to be here, and I assure you those of us on the planning committee appreciate your efforts.

U.S. Environmental Protection Changes Tack

Historically, environmental protection in the United States has relied on pollution control as its cornerstone. The major U.S. environmental regulations, the Clean Air Act, the Clean Water Act, the Resource Conservation and Recovery Act, and the creation of the Superfund to clean up toxic waste areas clearly reflect this emphasis. A great deal has been accomplished under these pollution-control and cleanup statutes, but much more needs to be done if we are to continue to make strides to protect our environment. We cannot achieve our environmental goals relying solely on complex, unwieldy, single-medium statutes to combat the problems of the future.

In the early 1990s, the environmental protection philosophy began to take on a new focus. New ways to prevent pollution received more emphasis, and we began to figure out new environmental solutions to our problems. New rules are now emerging for both industry and government in the environmental protection area.

When I became the assistant administrator in 1989, industry and government were often perceived as adversaries. Since that time, however, much has changed, including the name of my office — to reflect a more prevention-oriented way of doing business. Business and government leaders have identified some areas where our goals meet. The environment and the economy can work in harmony, and pollution prevention is the tool to successful accomplishments in both areas.

Pollution prevention is a good framework for defining the solutions that this symposium is seeking. We seek opportunities to lessen the worldwide pulp and paper industry's adverse impact on the environment and to improve economic efficiency at the same time. Over the last decade, U.S. consumers have begun to demand that environmental concerns be addressed in the manufacturing stage of a number of products.

For the pulp and paper industry, consumers are calling for cleaner products with better environmental performance and facilities with much less impact on neighboring communities. New processes and technologies are continually being developed to meet these demands. During this

symposium, we hope to identify appropriate emerging technologies for U.S. facilities and reach consensus on the major issues facing the pulp and paper industry as it struggles to meet its environmental challenges.

We have structured this conference to reach as broad an audience as possible among industry, consumers, environmentalists, and government regulators. We want to expand our understanding of potential solutions and identify and work through barriers to their implementation. The pollution prevention philosophy is resisted by some manufacturers because it entails added responsibilities, and by some in the environmental community because of the philosophy's inherent uncertainty.

Corporations Can Approach Pollution Proactively

In the past, corporate environmental managers were primarily concerned to be in compliance with existing environmental laws. Compliance was less daunting and far safer than attempting to forge new trails in pollution prevention. But this attitude has begun to change, especially with the creation of the Toxic Release Inventory (TRI) and greater involvement by the public, both as consumers and neighbors.

Today corporate managers are looking beyond compliance to see what their facilities are actually doing to their communities. Environmentalists are beginning to realize that costly prescriptive regulations do not always yield the cleanest environment over the long-term. Pollution prevention requires initiative, creativity, and trust. It can require additional investment for the short- and long-term. But many interested parties are beginning to realize that the investment can bring substantial returns — rewards that encompass far more than increased efficiency and monetary paybacks. The rewards include environmental benefits and higher customer satisfaction. Though environmental returns may be difficult to measure, we are confident that they are long-lasting.

Conclusion

Pulp and paper production has been a major industry in this country for many decades, and its manufacturing methods have at times been controversial. Government, industry, and groups of citizens have waged explosive debates over perceived actual and potential harm to the environment, over how much control should be in place, and over what costs are necessary or reasonable. During this meeting and other related gatherings, representatives from corporations, environmental groups, and government agencies can engage in an honest exchange of ideas. The government can serve a valuable role as facilitator and as a promoter of many pollution prevention efforts.

EPA has had substantial success in these efforts. Initiatives like the 33/50 program in which companies voluntarily reduce their TRI discharges by 33 and 50 percent and the Green Lights program, in which EPA and industry collaborate to change to new lighting technology, are excellent examples of the benefits of collaborative efforts between government, industry, and the public. EPA has been building rapidly on this record of success. Design for the Environment — one of our newest programs — has the potential to change the way chemicals are developed and used.

Design for the Environment (DFE) promotes the design, development, and applications of chemicals, processes, and better technologies within industry through a dynamic process of changing behavior. By building environmental concerns into the design stages of products, we can achieve pollution prevention results that will benefit everyone.

This symposium emphasizes the necessity of thinking proactively rather than reactively. The company that is able to anticipate problems and tackle them before they grow to be major obstacles to corporate success is the industry leader of the future. We have great hopes for this symposium. It offers the possibility that pollution prevention is not a buzzword but an accepted method of doing business in the pulp and paper industry, now and in the future, for the betterment of the environment and for the economic viability of the industry worldwide.

A Brief Introduction of the Pulp and Paper Industry Cluster

Martha Prothro
Deputy Assistant Administrator, Office of Water
U.S. Environmental Protection Agency
Washington, D.C.

I welcome you today in my capacity as the chair of the U.S. Environmental Protection Agency's (EPA's) Pulp and Paper Cluster. This cluster is not a new high-fiber candy bar but a group of agency managers committed to the notion that we can coordinate and, to a great degree, integrate agency actions that affect the pulp and paper industry. The cluster group's members are listed on the back of your program. I am very proud to work with such a distinguished group — all of whom are participating in one capacity or another in this conference.

Given the history of environmental law and regulation in this country, and the medium-specific laws and regulations that we have to deal with, we at EPA think the cluster group presents both an exciting challenge and a promising precedent for other programs. I believe this marks the first time the EPA has integrated its regulatory activities in so many different media (air, water, and soil) areas. We are proud of our accomplishments, though sometimes, like Pogo, we do feel as though we are confronting insurmountable opportunities.

According to the industry's own Toxic Release Inventory (TRI), the pulp and paper industry is the fourth largest industrial source of pollutants in the United States. More than 600 pulp and paper mills located in this country discharge about 370 million pounds of TRI pollutants — about 55 percent to the air, and 34 percent to receiving waters. As most of you know, in the late 1980s, the industry and EPA worked together on a study now known as the *104 Mill Study*. We found that virtually all bleaching mills in the industry had dioxins and furans in their effluent and wastewater treatment sludges.

Since then, the industry has made a great deal of progress. Some mills have made significant improvements in pollution prevention, and some in their control technology. But most of us here agree that more work needs to be done.

On the other hand, we need to keep in mind the economic importance of this industry to our nation. Pulp and paper manufacturers employ almost 200,000 people at more than 500 facilities located in almost every State. The entire industrial category, including companies that convert pulp and paper into finished products, employs another 600,000 Americans at 6,200 facilities. The payroll is more than $27 billion annually.

Paper industry spending for new plants and equipment from 1991 through 1992 is an estimated $14 billion. Spending for environmental protection is projected at $1.9 billion during that same period (or about 15 percent of the industry's total capital expenditures). In the March 1992 edition of *Fortune* magazine, George Adler of Smith Barney states that the paper industry is to the United States what oil is to Saudi Arabia. So we must address the question of how to further the goals of environmental protection and economic strength. This duality is at the heart of the pollution control controversy in our pulp and paper mills. Change means movement, movement means friction, friction means heat, and heat means controversy. But, as Bertrand Russell once said, the most savage controversies are usually about matters for which there's no good evidence either way.

This conference provides an opportunity to review the evidence and to move from controversy to consensus. In the long run, as President Bush has said, successful environmental protection is a prerequisite to solid sustainable economic growth. That is EPA's belief vis à vis this industry.

Later in the symposium, you will have an opportunity to hear more about the Pulp and Paper Cluster and our coordinated approach to developing new technology requirements for air and water pollution. Because the Cluster's goal is to promote pollution prevention, we have supported this symposium financially and many Cluster members have worked hard on this effort. We hope you will find the information about the Cluster and the Cluster itself useful. We think its success will mean a greater appreciation and knowledge of the opportunities for pollution prevention in this industry.

It has been said of some government officials that even if they attended a conference on creation, they would remain loyal to chaos. I assure you, however, that we at EPA have not approached this symposium from that point of view. We are here to listen and learn as I know you are.

A Profile of the U.S. Pulp, Paper, and Paperboard Industry

Richard E. Storat
Vice President, Economic and Financial Services
American Paper Institute
New York, New York

The primary raw material for the myriad of products that we produce and you use in your daily lives is largely fiber or cellulose derived from trees — a renewable resource. The industry formerly obtained its fiber from another recyclable and renewable resource, namely cotton, in the form of rags. When demand outstripped that source of cellulose, we discovered how to obtain cellulose from trees. The renewability of this resource is underscored by the fact that nearly 3 billion seedlings are planted each year, with forest growth exceeding harvests and losses to natural causes; in fact, the United States has 20 percent *more* trees today than we had just 20 years ago.

Pulping and bleaching processes separate the cellulose in trees from other constituents such as lignin with as little damage to the natural cellulose fibers as possible. The kind and extent of pulping depends on the end-use characteristics needed for particular products; the greater the cellulose content, for example, the greater the strength, brightness, longevity, softness, and absorptive capacity. Finally, paper and paperboard mills in turn use the pulp to make a range of commercial and consumer products: printing and writing papers, newspapers, packaging, sanitary and personal care products, and corrugated containers.

Pulp and Paper in Perspective

With only 5 percent of the world's population, the United States has 12 percent of the world's paper and paperboard mills and 16 percent of the world's pulp mills. The United States manufactures 30 percent of the world's paper and paperboard and 35 percent of the world's pulp. Last year, 544 mills located in 42 states produced 79.4 million tons of paper and paperboard products and 9 million tons of market pulp. In 1991, the paper and allied products industries employed nearly 700,000 people with a payroll topping $28 billion and generated sales of $122 billion. U.S. mill production amounts to 5 percent of the total value of U.S. manufacturing output, placing pulp, paper, and paperboard among the nation's top 10 manufacturing industries.

As the world's top producer, U.S. paper and paperboard mill output is greater than the combined total output of the next four countries — Japan, Canada, Germany, and China. Of the world paper and paperboard market, the United States has 30 percent, Japan, about 12 percent; Canada, 8 percent; Germany, 6 percent; and China, 5 percent. In world market shares of wood pulp, the United States has 35 percent; Canada, 16 percent; Japan, 9 percent; the former Soviet Union, 7 percent; and Sweden, 7 percent, according to a United Nations Capacity Survey (U.N. Food Agric. Ass.. 1992).

Continuing a long-term trend, total U.S. paper industry exports rose in 1991 to record heights, up 11 percent to 21.4 million tons, valued at $9.7 billion, in spite of slower world economic growth and global overcapacity in several paper industry products. This strong export performance can be attributed to several factors:

- relatively better demand in foreign markets;
- fundamentally sound exchange rates;
- greater global market focus by U.S. producers; and
- a very competitive U.S. cost structure.

Perhaps the most significant of these factors is the competive cost structure.

Labor, Capital, and Capacity Costs

Comparative unit labor costs are a key measure of competitiveness because they summarize the combined influences of productivity, compensation, and exchange rates. Partly as a result of favorable exchange rates but mainly as a benefit from productivity advances, U.S. paper industry unit labor costs have held flat since 1982, outperforming other major paper-producing industries around the globe (see Fig. 1).

A *Fortune* cover story, called "How American Industry Stacks Up," analyzed the competitiveness of 13 key U.S. industries relative to Japan and Europe. On its "report card," the U.S. paper industry was one of only two industries awarded an "A," which implied "a dominant position in the world, one not likely to erode significantly in the 1990s." *Fortune* also noted that "the United States leads not just because it has a lot of trees. American companies also have relative lower labor and energy costs, and they have invested more than $100 billion since 1980 to raise productivity and underwrite expansion into new products and markets."

The pulp and paper industry requires enormous amounts of capital — $16.7 billion in 1990. Even after the sharpest spending cutback in recent history, investments in 1991 neared $12 billion and will top $10 billion again this year. From 1980 until the end of 1991, a new capacity of almost 21 million tons was added to U.S. mills. As the rate of capacity expansion slows, 2 million additional tons of capacity are still expected to come on-line in 1992.

During the 1980s, the portion of industry capacity in paper mills larger than 500,000 tons per year almost doubled — from 18 percent to more than 32 percent. Pulp mills followed a similar trend. Almost 60 percent of the industry's capacity exists in machines that were either newly installed or extensively rebuilt during the past 10 years. This newest segment of the U.S. paper industry is larger than any other nation's entire industry — more than 1.5 times the size of the entire Japanese paper industry.

Industry capital spending also translates into exceptional productivity gains. During the 1980s, productivity rose 37 percent, providing the basis for paper industry unit labor costs that are among the lowest in the world, measured in dollars.

Changing to meet new customer demands has required significant capital resources. The growing

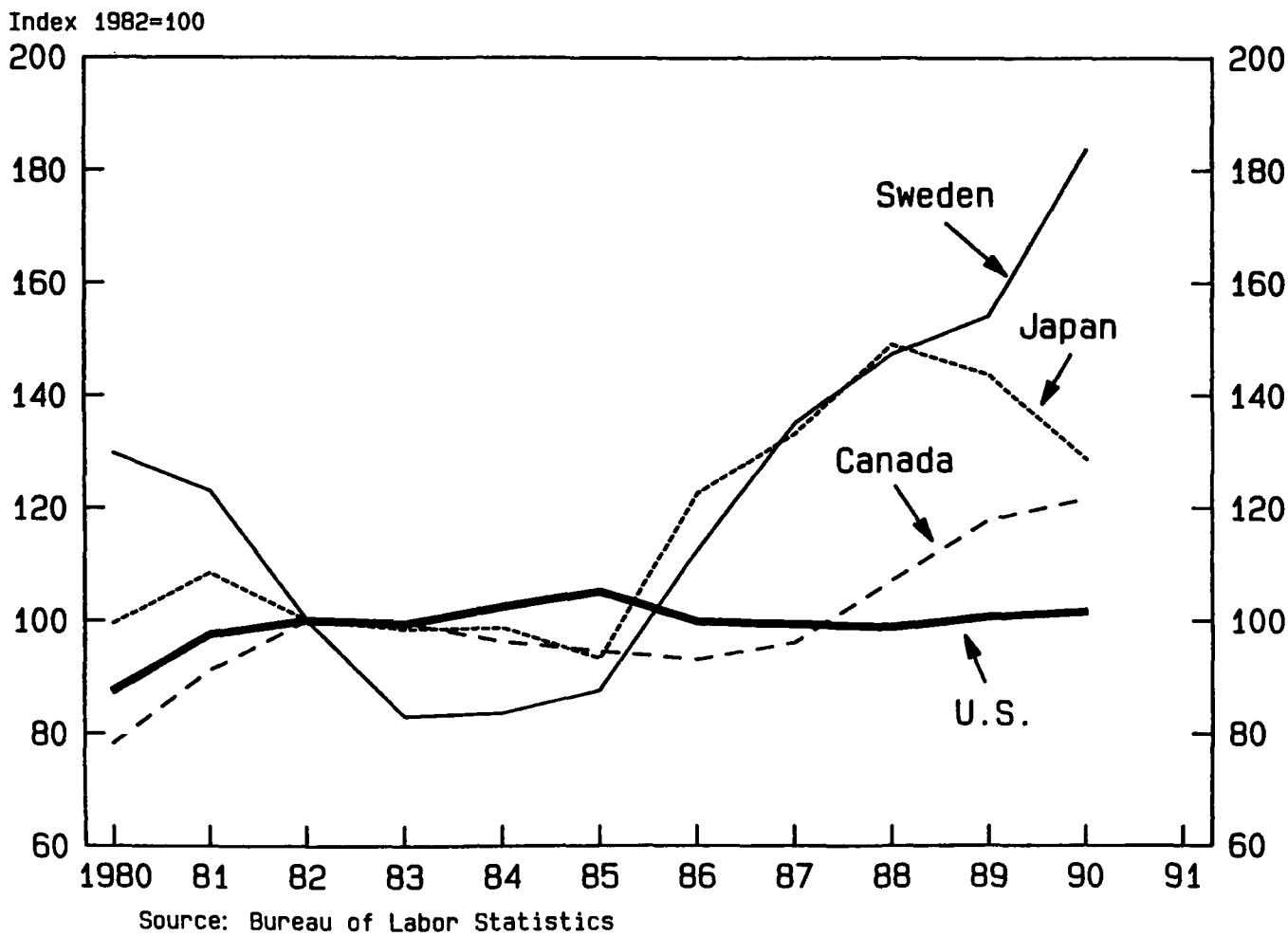

Figure 1.—Unit labor costs trends in the paper industry. Source: Bur. Labor Stat. (1991); Am. Paper Inst. (1991).

demand for paper products containing recycled fiber is one example. As a result of a multibillion dollar investment program, fiber consumption from recovered paper is growing more than twice as fast as overall fiber consumption, and this trend is projected to continue to 1995 and beyond. The rate at which the U.S. industry uses recovered fiber jumped to 29 percent in 1991 from less than 24 percent only six years ago.

Last year, 31 million tons of paper and paperboard were recovered in the United States — including half the newspapers and close to 60 percent of corrugated boxes. With last year's recovery rate at over 35 percent, the industry is on track to achieve its voluntary 1995 goal to recover 40 percent of all paper Americans use for domestic recycling and export. By 1995, more paper will be recovered for recycling than will be discarded to landfills.

Primarily by using its own waste by-products, the U.S. paper industry generates more than 56 percent of its energy needs. Over the past two decades, oil consumption has been reduced by nearly 66 percent; natural gas consumption by 10 percent; and fossil fuel and energy consumption per ton of paper by 46 percent — while production grew by 60 percent. In addition, over 50 percent of the industry's energy is more efficiently cogenerated, saving the energy content of nearly 24 million barrels of oil annually.

Capital Intensity

In part, how much an industry has invested per employee defines its capital structure. Currently, on average, each employee in our industry is backed up by more than $100,000 of plant and equipment. This level is more than twice the average of domestic manufacturing industries and, excluding petroleum, is matched only by the chemical industry. When capital investment is measured as a percent of paper industry sales, its intensity has been growing at an average rate of 2.7 percent per year for over two decades. Contrast that to U.S. manufacturing in general, which has traced a much slower growth path.

The paper industry is the most capital intensive industry in the United States. In the last decade, it was twice as capital intensive as the all-manufacturing average, twice as capital intensive as the chemical industry, and significantly above the primary metals industry. This feature, more than any other, distinguishes the paper industry's capital structure from that of other basic manufacturing industries (see Fig. 2).

The industry's capital intensity is extremely high. During the 1980s, on average, 10.7 cents of every sales dollar went for capital spending. Until recently, most of the industry's capital spending was provided for by cash flow, allowing for some shortfalls during the early 1980s. From 1989 to 1992, however, cash flow fell far short of capital spending requirements. By doing so, the industry positioned itself well for world-class competitiveness during the 1990s. But it also shouldered a huge debt along the way.

The industry has peaked in its cyclical pattern and must now get "end of cycle" returns on these large investments to retain the long-term financial strength that will enable it to remain globally competitive.

Being capital intensive also means having to sustain a larger asset base relative to sales and having higher operating rates — in the case of the paper and pulp industry, the highest of any in U.S. industry, averaging 92 percent over the long-term, compared to an 82 percent manufacturing mean and a 75 percent rate in some industries like transportation.

To maintain and improve existing mills and to increase capacity to keep pace with anticipated demand in domestic markets alone, the U.S. paper industry will need to spend some $100 billion and add about 19 million tons of new capacity in the 1990s.

Pollution Abatement Spending

During the 1970s, environmental control expenditures comprised 23.5 percent of capital spending. While remaining in the $400 million per year range during the 1980s, such costs averaged only 8.1 percent of industry investment (see Fig. 3). Capital outlays for environmental compliance, having risen dramatically over the past few years, now exceed $1 billion per year. As a result, the paper manufacturing process today uses 60 percent less water per ton of product produced than it did 23 years ago. Biological oxygen demand of industry wastewaters has been reduced by 70 percent since the first phase of implementation of the Clean Water Act, even though paper production has increased by 50 percent since then.

While this recently stepped-up spending does include the industry's response to dioxin-related concerns, none of the multibillion dollar investments in recycling facilities, none of the billion dollar-plus investments that will be required to comply with the recently enacted Clean Air Act, and none of the associated operating and maintenance costs are reflected in these data.

Extrapolating from recent trends and using the pollution spending projections developed by Data Resources, Inc., we estimate that environmental

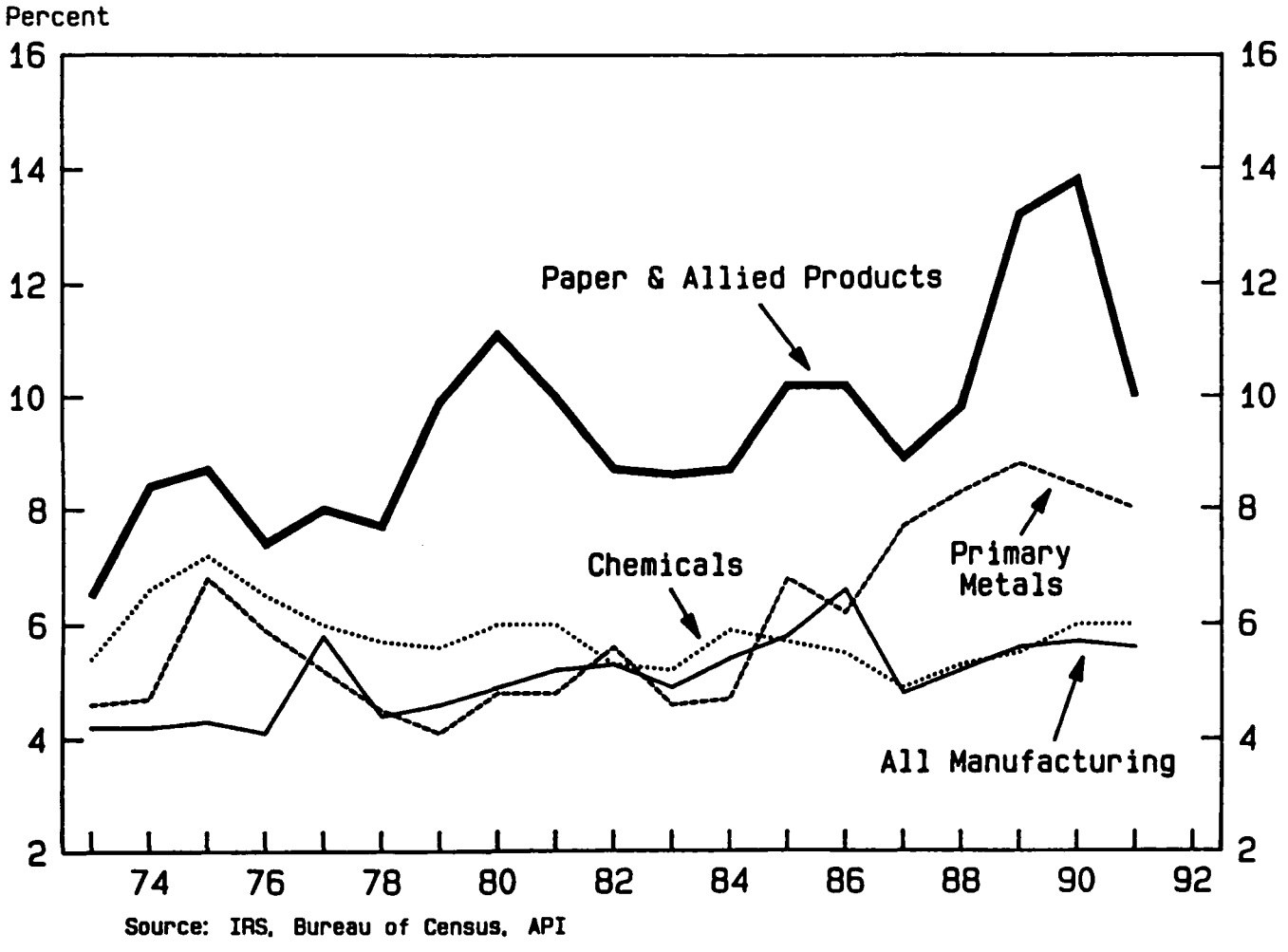

Figure 2.—Comparative capital intensity (capital expenditures as a percent of sales). Source: Intern. Rev. Serv. (1991); Am. Paper. Inst. (1991).

spending may claim about 20 percent of industry capital during the 1990s. That's the capacity equivalent of 18 world-class paper machines each capable of producing 500 tons per day.

The costs of future environmental regulations are especially high for a business as capital intensive as paper.

Large capital investments relative to sales are required for the industry to remain globally competitive. In turn, the industry's global competitiveness enables it to run at the 90-plus percent operating rates that translate into low unit costs. Low-cost operations relative to other global competitors generate the cash flow that provides the investment capital to sustain the industry's position, closing the loop. If any one link is broken, the system fails. Since committed capital is neither easily nor inexpensively redirected, one needs to consider carefully the impact of policy prescriptions for the paper industry that may be proved wrong in the long-term .

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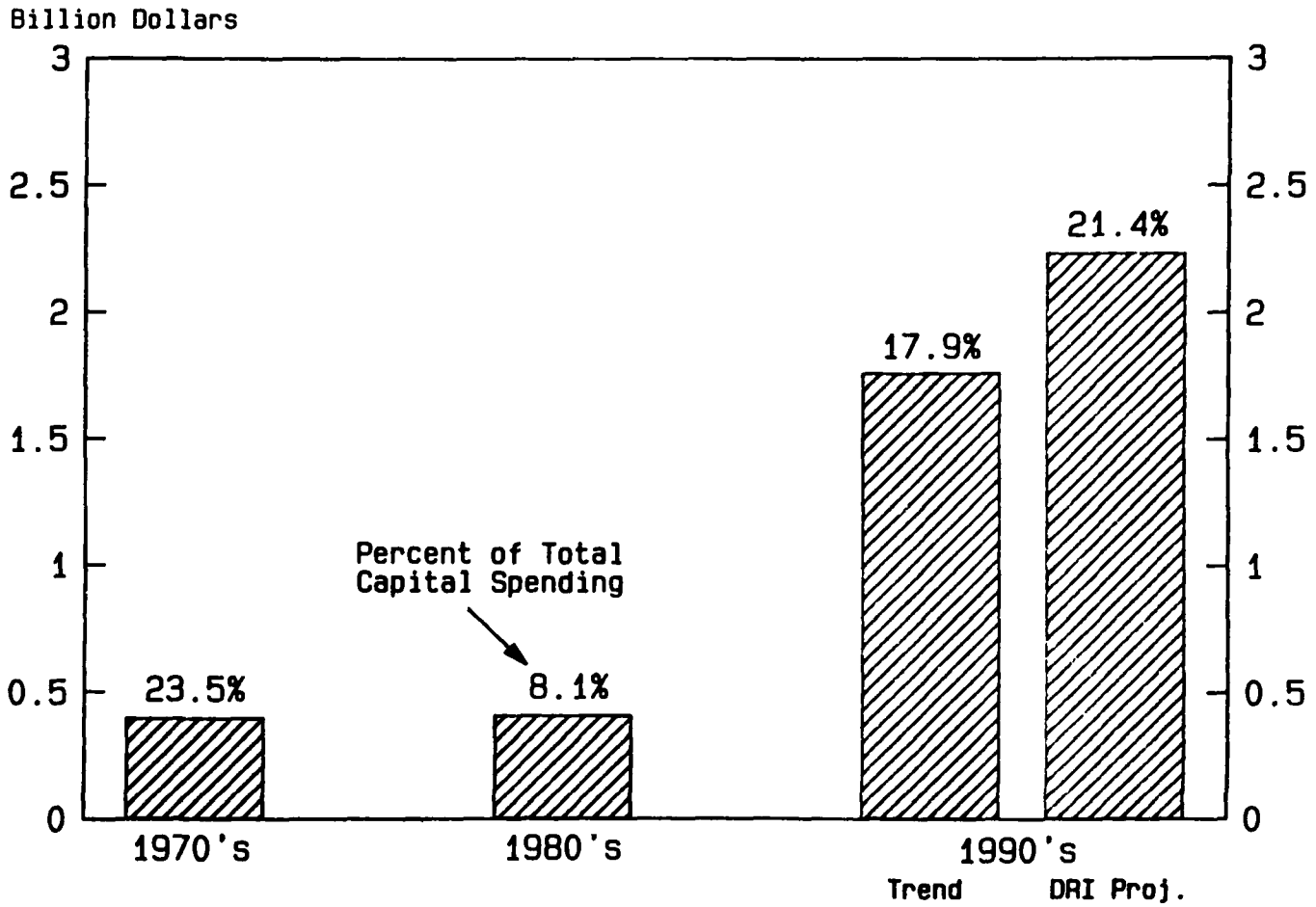

Figure 3.—Pollution abatement expenditures for U.S. paper, paperboard, and wood pulp mills. Source: Natl. Counc. Paper Indus. Air Stream Improve. (1990); Am. Paper Inst. (1991); DRI/McGraw Hill (1991).

Pollution Prevention and Life Cycle Assessment

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I am here to talk about the science, practice, and application of life cycle assessments or analyses (LCAs), and how we may improve this tool and use it to pull together a methodology that may help us make better environmental decisions. Ultimately, our environmental decisions are crucial, and I want to help us make those decisions better. So let me begin this presentation on the background and use of LCAs with a textbook definition.

LCAs are a three-part process: an inventory of a system's inputs and outputs; an impact assessment; and an improvement analysis. The first part is an inventory in which one models a system and evaluates all inputs and outputs across its boundaries. As the entire system is included in the inventory, a great deal of data is collected in this step, which is also the only step in the LCA process that is truly well developed at this point.

The second part of an LCA is the "impact assessment." What do these materials and energy releases do to the environment? This part of the LCA process is still in conceptual development. The third part of the LCA encompasses an improvement analysis. The purpose of making the inventory, the impact assessment, and the improvement analysis is proactive: LCAs should reduce the environmental burden and resource consumption associated with products, packaging, processes, or activities. I borrowed these words from the LCA advisory board of the Society of Environmental Toxicology and Chemistry (SETAC), but the important consideration is that LCAs be used to make overall improvements.

Figure 1 is the famous SETAC triangle drawing of the LCA concept. Life cycle assessments help us look beyond our traditional company boundaries to see the effects of our processes upstream and downstream. In fact, the various decisions that we make affect both sides of the equation. LCAs are a way to visualize the effects of our decisions on all stakeholders, our internal and external customers.

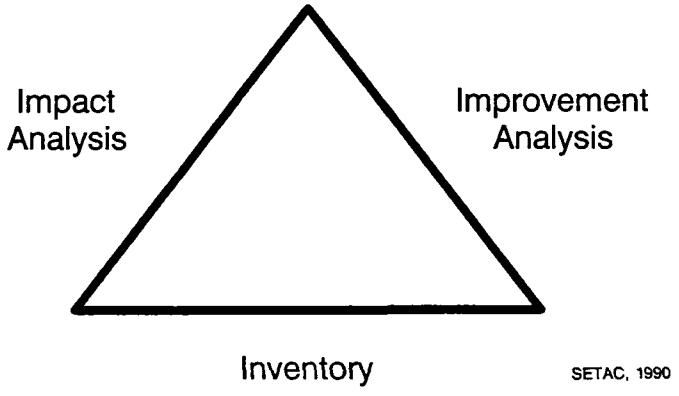


Figure 1.—Triangular Model of Life Cycle Assessment Components.

In addition, LCAs carry us to another degree of detail; they take into account multiple issues. I am sure all of us have our favorite issues that need to be included in an LCA. But I think we would also all agree that within the scope of this process rages a great debate. Really, what LCAs do is help us deal with this debate — not to make our environmental decisions for us, but to help us deal with them more effectively.

Single-issue Charlie

To give you an example of my experience with this debate, let me tell you about a friend of mine, Single-issue-Charlie, and his efforts to create better packaging for the environment. Consider, for a moment, the issue that Charlie is dealing with when he takes on this task. He is committed to better packaging, and he has been told to do it, so the will to act is not an issue here. All Charlie has to do is

jump into the fray. "The obvious thing to do," he says, "is to make this package biodegradable."

I don't think any of us now, unless we are interested in composting, would talk about biodegradable products as a solution to municipal solid waste. Single-issue-Charlie, though, is up on the facts and knows that packages should contain recycled content and be recyclable. In addition, Charlie also *wants* to make his packaging recyclable. But he has also heard some stuff about source reduction and now his troubles start; he knows that there are trade-offs between source reduction, recycling, and recyclability, but he doesn't really know what to do to balance them.

To make matters worse, Charlie also wants to put a label on his packaging, and when he thinks about this label, he realizes that a variety of labeling regulations exist across this land. Notwithstanding that the Federal Trade Commission (FTC) has helped us here, Charlie still has questions on this score. Finally, he may discover that various regions want it one way; other regions require something different. New Jersey may want it one way, and his friends from Oregon may want it another way entirely. The net effect is confusing; what is poor Charlie to do? His dilemma is portrayed by the cartoon in Figure 2.

Charlie may, however, turn away from single-issue viewpoints to LCAs as a way of helping him sort out the issues.

The Status of LCA Development

Life cycle assessments are really not very magical. LCA methodologies were here in the early 1970s, when they were really nothing more than an input/output diagram or model. The LCA framework is an engineer's dream: good stuff with lots of numbers and systems to analyze. SETAC is one of the groups working on this development. Its advisory board has focused on trying to develop this concept and methodology into a global vision. The U.S. Environmental Protection Agency (EPA) is also taking a very active role in the development of this methodology, along with several other groups, including the pulp and paper industry. I will concentrate my remarks on SETAC's contributions in this area.

SETAC is trying to advance the science and practice of this methodology overall, in a way that makes sense and uses good science. To do that, it serves as the focal point for issues and development, and it facilitates and coordinates the overall experiments with this methodology. SETAC's LCA advisory board, or steering committee, of which I

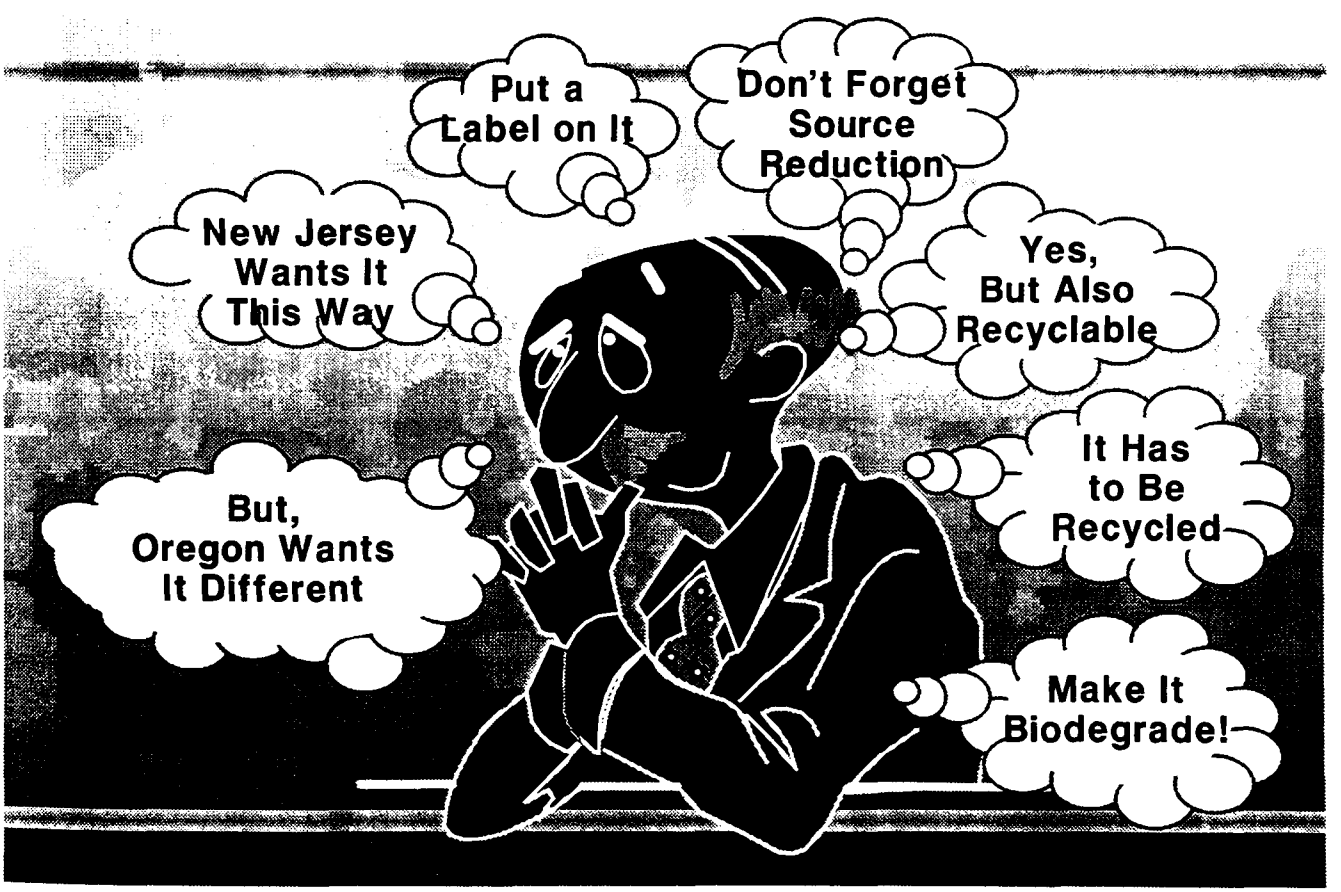


Figure 2.—What should Charlie do?

am a member has worldwide and multisector representation; it also tries to operate on consensus.

What we are trying to do now is form committees to help with the overall development of the methodology. Now being a group that is excited about triangles, we revisited our original LCA model and decided that it needed to be more detailed. In fact, a life cycle assessment is really only as good as the goal definition and the scope of the study. It is very important to spend time defining your system and understanding the interrelationships among its various parts. The revised LCA triangle and these interrelationships are shown in Figures 3 and 4, respectively.

The first step is to define the goal and purpose of the study and to characterize the system that you are analyzing. Then you can begin the inventory. Details of an inventory assessment are shown in Figure 5. In essence, what you are doing is categorizing your inputs and outputs all the way back to Dino the dinosaur, if you can find him. The inventory details the system's life cycles, from raw material acquisition through waste management. These inclusive cycles have been termed "cradle to grave," "earth to earth," "dust to dust," but the bottom line is to achieve an understanding for all potential inventory items and potential impacts that are associated with a particular industrial system.

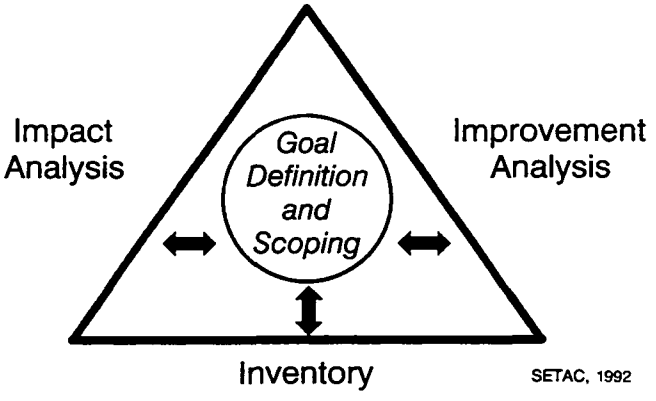


Figure 3.—Refining the LCA concept.

Defining Systems

A life cycle assessment doesn't analyze products; it analyzes systems. Systems make products, but the first thing to do is make sure that your system is well defined. This step takes you into very simple engineering, but it can be an engineering nightmare to define your system. If you walked into one of our paper plants and asked to see the system involved in a particular paper-making process, I think you would be faced with a confusing albeit interesting collection of pipes and valves and systems that are linked together through many subsystems. You will need to spend more than a little time breaking your system down to its various components.

Figure 6 shows the types of inputs and outputs that are of interest from a life cycle perspective. This process has been well documented by SETAC, and EPA will soon publish a guidance manual on how to do an inventory. Therefore, instead of describing the inventory process, I will consider an example of its applicability to the pulp and paper industry.

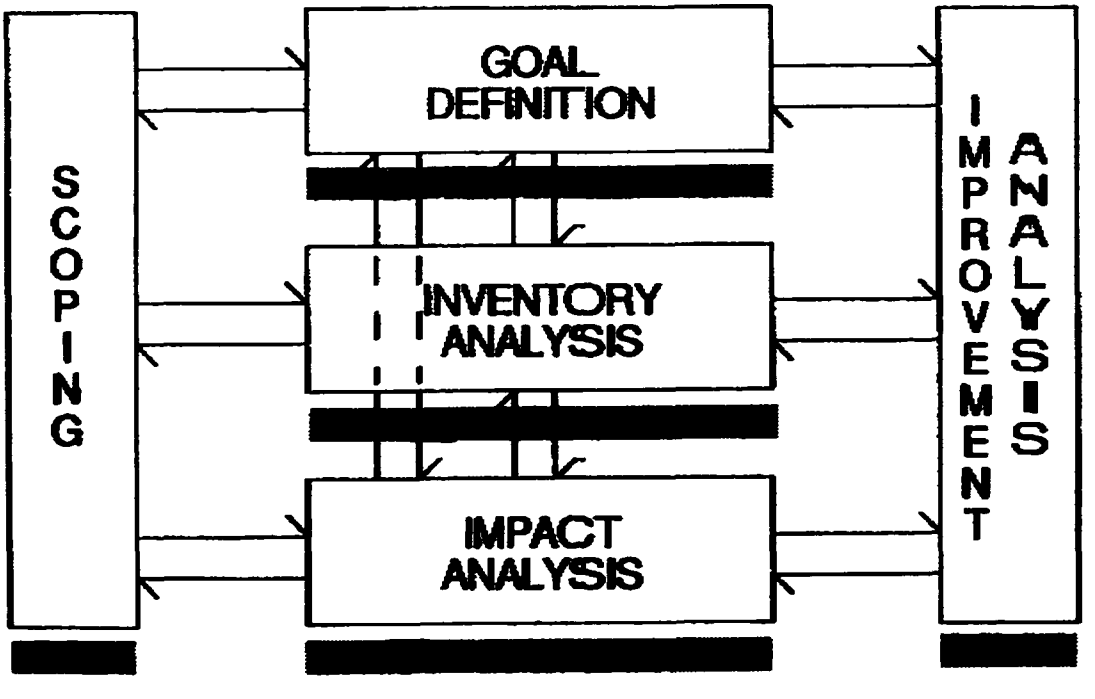
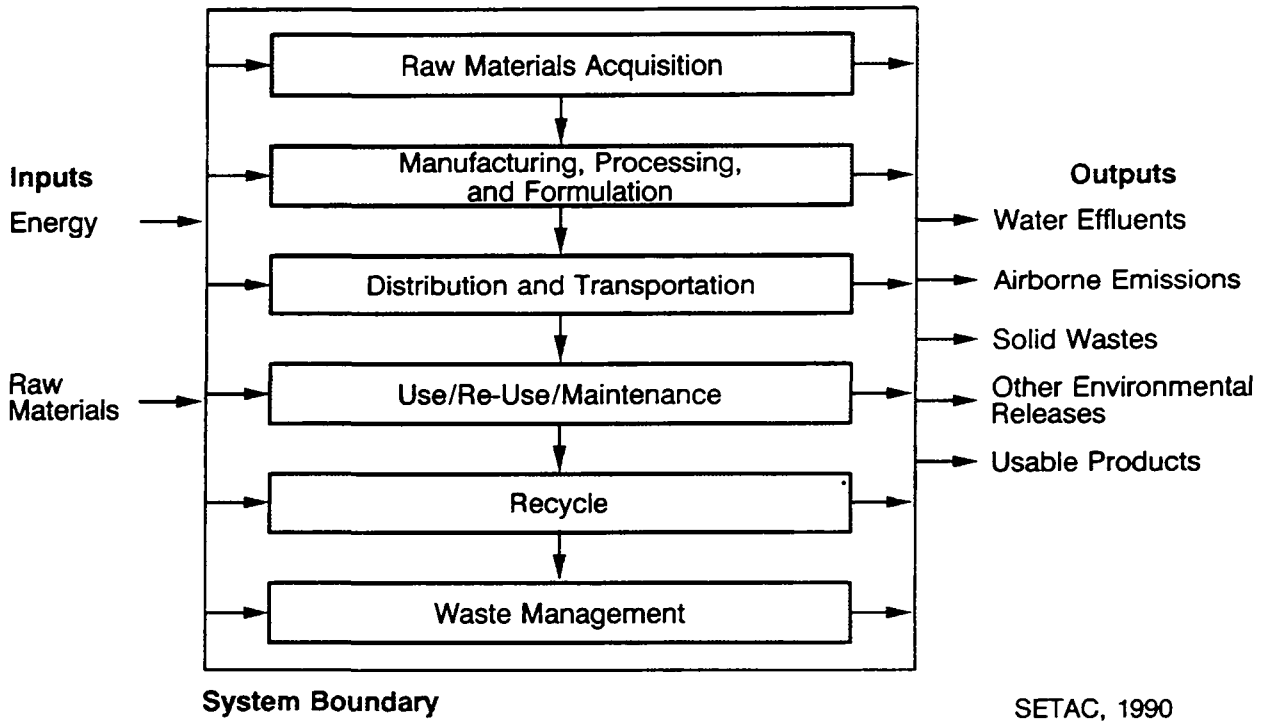


Figure 4.—Interrelationships among the major LCA components.



SETAC, 1990

Figure 5.—A sample LCA inventory.

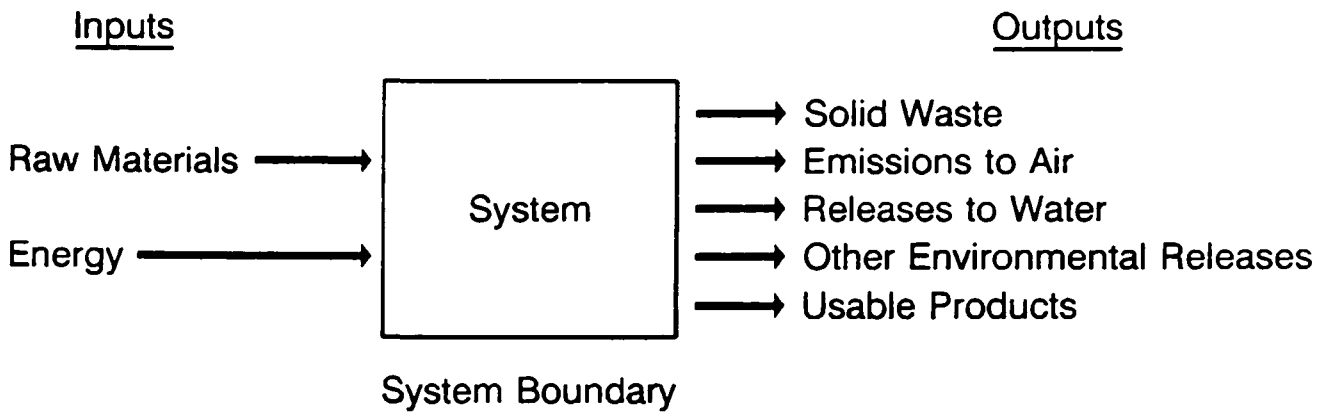


Figure 6.—Inputs and outputs of interest in LCA assessments.

SETAC, 1990

Suppose that I am interested in analyzing the environmental effects of bathroom tissue, and that I am looking at recycling. I might at first consider closed-loop recycling. Figure 7 is a simple closed-loop recycling system. In essence, what we have are the production processes of bathroom tissue on the bottom, and a recycling loop in square number four, a closed-loop system. Unless some of you know something that I don't know about bathroom tissue, it hardly lends itself to a closed-loop recycling process, so this simple diagram doesn't apply. Indeed, recycling wastepaper into bathroom tissue is an open-loop process.

When you look at open-loop recycling in the context of a life cycle assessment, you need to look at the true original processes. Assume, for example, that the recycled fibers source for the bathroom tissue comes from office paper. In this context, which is illustrated in Figure 8, systems one through three are the individual processes related to the production of office paper. The bottom systems, four through six, are the ones related to bathroom tissue, and system seven links the two procedures. To make a life cycle assessment of this recycling process, I have to look at both of these systems and do an entire analysis, looking at the impacts of various factors, for example, the energy savings in recycling.

Figure 9 is a hypothetical graph of energy savings as a function of recycling. In this case, if our purpose is to maximize recycling, and we are not concerned with energy consumption, then clearly we want to be over to the 100 percent recycling line.

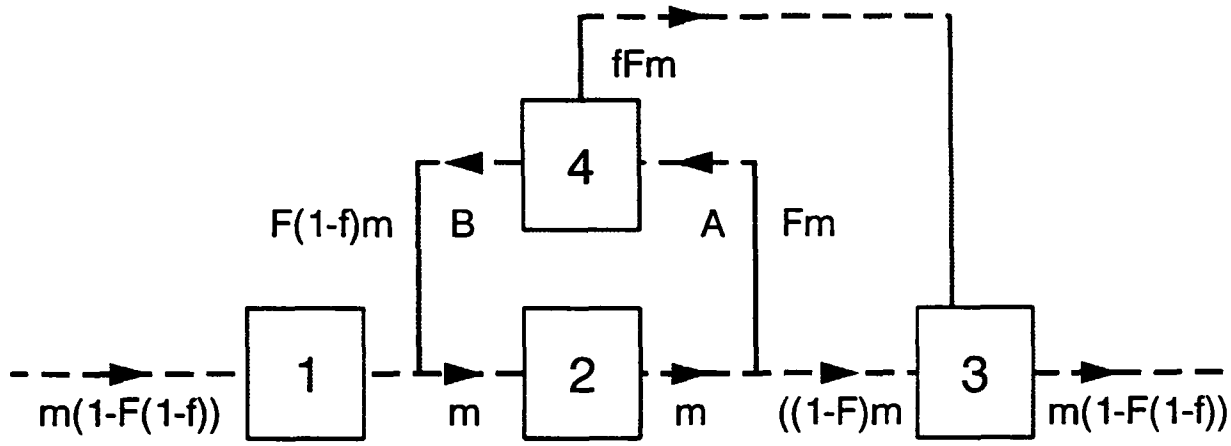
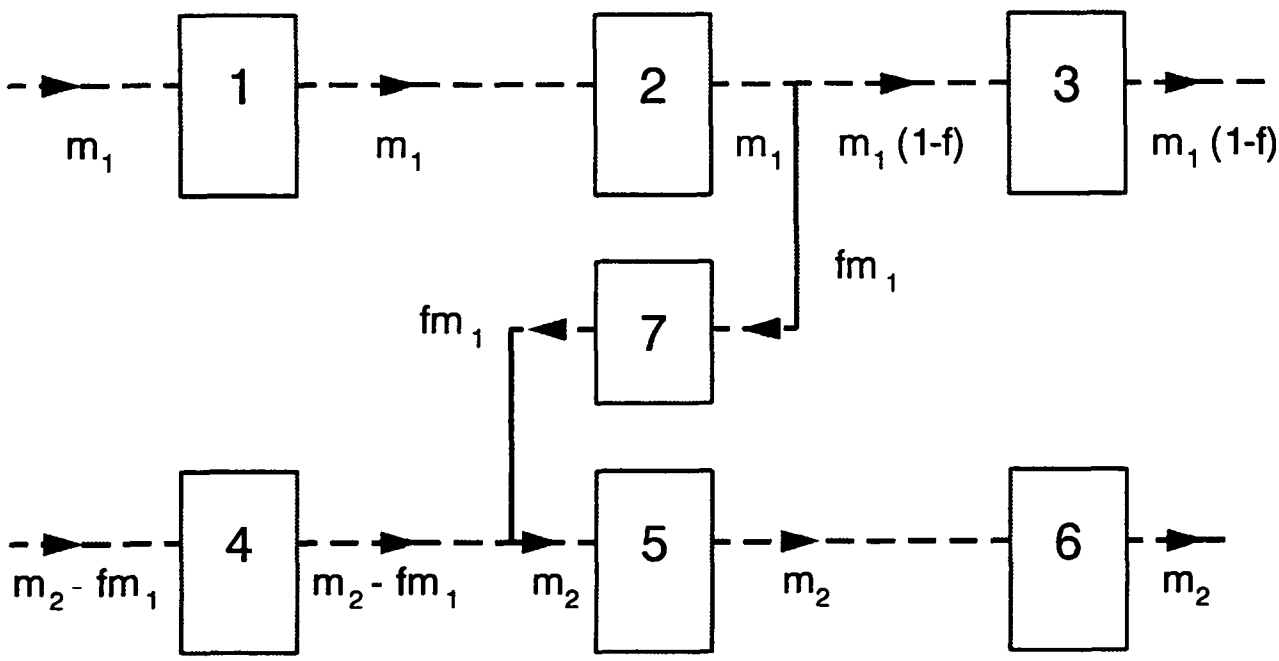


Figure 7.—A simple recycling system.



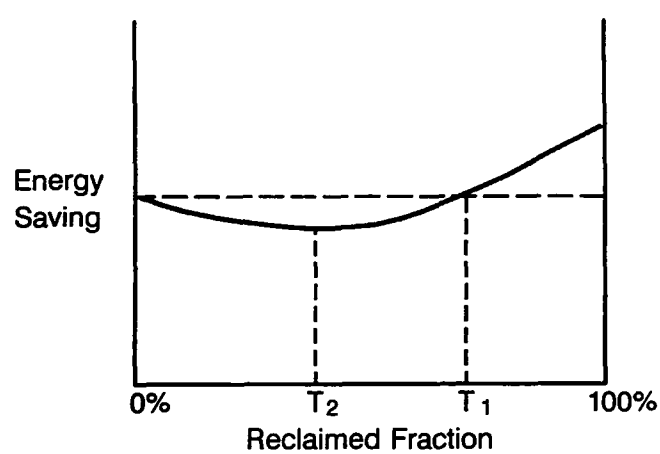
Baustead, 1992

Figure 8.—An open-loop recycling system.

On the other hand, the logic of any industrial system is that the more "stuff," it picks up to recycle, the more energy it will require to gather and reprocess these materials appropriately. Therefore, what we probably should do is seek to balance energy and recycling. If this is our goal, we may be better off dealing with T_1. But if we want to maximize energy and recycling at minimum energy, we may even consider T_2 as our goal.

European Eco-labeling

Another example that I want to discuss concerns the European Eco-labeling program, because it is based, in fact, on a life cycle concept. In essence, the Europeans are considering the labeling of products that meet certain hurdles and barriers.



Baustead, 1992

Figure 9.—Hypothetical graph of energy saving as a function of reclaimed fraction.

To accomplish this task, they are looking at emissions from four systems based on LCA perspectives. They award load points on the basis of good to worse within the category. Then they go through a weight factor analysis of potential improvement within the industry versus the level of concern and assign points against that.

Finally, they add these figures together to produce a rating. If your product is among the 25 percent best in the industry against these factors, then you could be awarded an Eco-label. This is not to say that you need an LCA to do Eco-labeling. On the other hand, if you did perform life cycle assessments on your processes, clearly it would help you in terms of addressing Eco-labeling schemes.

I want to leave you with three interrelated ideas regarding LCAs:

- You need to be very careful with how you use life cycle assessments.
- They are extremely valuable as internal guidance tools to companies.
- They can be very dangerous in the public context unless they are appropriately framed and unless you put forth all the assumptions that go with them.

Their value is largely related to the possibility of including different perspectives in each analysis and in evaluating multiple issues simultaneously. Their danger relates to the fact that the methodology is still emerging.

I think LCAs — like the principles of total quality management — are a very effective tool. They are the tool of the future because they can help us consider pollution prevention and other environmental issues in a different light. I am absolutely convinced that if we work hard on this technique and really focus on pollution prevention, the pulp and paper industry has much to gain from the effort.

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The Pulp and Paper Industry's Long-time Commitment to Environmental Quality

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Because the pulp and paper industry operates in a worldwide marketplace, it has been quick to recognize the importance of having a proactive approach to environmental quality.

In 1943, the industry formed the National Council for Stream Improvement and, in the 1960s, expanded it focus and name to the National Council for Air and Stream Improvement (NCASI). Today, NCASI operates a cooperative research program to identify and solve pollution problems and to monitor the industry's progress. This national program includes a high degree of technical cooperation with existing regulatory agencies.

Four regional NCASI centers address all aspects of the industry's activities in conjunction with two aquatic biology research centers and two forestry wildlife habitat research centers. These NCASI activities drive many of the pollution prevention efforts within the industry.

A good example is the aquatic ecological study that has been under way for more than 15 years and has provided valuable insights into the effects of industry discharges on the aquatic environment. The study results form the basis for judgments on how best to optimize our successes. Other long-term NCASI research led to the widespread use of secondary-waste treatment in U.S. papermaking.

The recently approved environmental health and safety (EHS) principles and forest management principles are testimony to management's commitment to pollution prevention. Adherence to EHS principles is a condition of membership in the American Paper Institute (API). This commitment illustrates the industry's willingness to continue its history of voluntary efforts to maintain environmental quality and preserve our natural resources.

The pulp and paper industry operates on a natural resource base that is unique and renewable. We devote our energies to protecting and enhancing that uniqueness.

Other indicators also show that the idea of pollution prevention is alive and well. U.S. Environmental Protection Agency Administrator William Reilly's industrial toxics program has been embraced by Champion International Corporation (CIC) and others in the industry. While only a limited number of the 17 chemicals in the program have implications for our industry, we moved swiftly to line up behind the idea. The 33/50 goals will be met as agreed.

The dioxin issue was also part of the industrial toxics program. The industry's voluntary program had the participation of all affected companies, and the results bear repeating as a prime example of voluntary pollution prevention action.

When trace amounts of dioxin were discovered in emissions and determined to be an unwanted by-product of the papermaking process, the industry, with the help of NCASI, mobilized its resources. The result of the industry's voluntary effort is that today's 105 U.S. paper and pulp bleaching mills annually produce less than 1 percent of all dioxins in this country. Dioxin is no longer detectable in most kraft pulp mill effluents, even though more capacity exists in mills today than in 1985; and detection limits are also significantly lower and more accurate than they used to be.

The industry's anti-dioxin efforts were source reduction in the truest sense. A substance was voluntarily reduced through efforts that included process modifications, substitution of raw materials, improvements in housekeeping, and

training. The industry is proud of this record and agrees with Mr. Reilly that it exemplifies the efforts that his agency seeks to encourage.

In addition to reducing the unwanted formation of dioxin, CIC and other companies have increased their capability to analyze for the presence of minute amounts of compounds. CIC has invested more than $1 million to build and equip an ultratrace lab that can quickly and accurately track its dioxin reduction program. Our in-house labs are as sophisticated as commercial laboratories. This capability is a major asset in our scientific research and product development programs.

The kraft process has evolved as the principal papermaking process primarily because of its inherent pollution prevention opportunities. The process allows for the in-process recycling of waste streams leading to the destruction and recovery of chemicals for reuse. It provides for treatment of by-products for recycling and it allows for treatment prior to disposal. Over the years, the process has lent itself to development, which has resulted in greater efficiencies and reduced environmental impacts. Energy generation optimization is one of the most significant attributes of the process.

At CIC, as at other mills, more than 50 percent of all energy needs are supplied by recycling process streams, bark, hog fuel, and sludge. In some locations, we act as a local recycler, using tire chips as a substitute for coal. This recycling method provides significant benefits to the surrounding countryside — the life cycle of the ubiquitous discarded tire ain't what it used to be.

Conservation, recycling, reuse, and reduction principles are continuously applied by CIC personnel who plan and operate kraft pulping and bleaching facilities. Recycling also takes place outside of our processes. CIC has successfully developed a waste product from a nonintegrated paper mill into a raw material for use in the manufacture of cement.

At CIC's Hamilton, Ohio, plant, primary sludge is put through a drying and deodorizing process and shipped for use as a mineral source after it has passed through a cement kiln. This process avoids disposing of material in a landfill, conserves natural resources that would otherwise be required for manufacturing cement, and has a positive effect on our long-term capital spending requirements.

Another example of CIC's recycling efforts is the use of boiler ash in potting soils. We also recycle bark for use in landscaping practices — this, of course, is the bark we don't use as a fuel source. We're conducting research in using filter cake as an ingredient in nonfood packaging materials and as an absorbent material with an emphasis on groundwood operations. These efforts to reduce inevitable waste have a high profile among our employees. They see the environmental benefits. At Champion, we also have a team marketing tall oil and turpentine, two other kraft pulping by-products. This team is always on the lookout for recycling opportunities to minimize the waste burden.

Each of CIC's mills is part of a program to cut waste. We call it Conserving Our Resources Everywhere (CORE). CORE gives everyone an added incentive to develop ideas to reduced waste and improve our handling of waste materials.

CORE and other programs involving our employees focus on what they can contribute to environmental conservation. Command and control will only take us so far. The rest of our progress will be attained by personal commitment to doing the right thing. If you think about what you do today and what you did yesterday, I'll bet you can measure a contribution.

A discussion of pollution prevention in our industry is not complete without recognition of our commitment to recycle 40 percent of production tonnage. At CIC, we are considering an $85 million facility to process 500 tons per day of newsprint and magazines to be collected in Houston, Texas, using relatively new technology and a brand new collection and separation program that has been developed from scratch. Our other mills are also in the voluntary recycling business, using magazines, newspapers, office waste, and even milk cartons. We are part of the solution and we intend to keep it that way, balancing our cost, quality, and worldwide competitive position objectives along with our environmental objectives.

Every new major capital project in the industry includes plans to minimize detrimental environmental effects. Other objectives include customer-driven quality requirements, cost considerations, and competitive conditions. Environmental conditions drive projects from the standpoint of how much we spend and when we spend it. The effect of environmental conditions on the timing of capital spending is often overlooked — partly because environmental considerations are not necessarily dictated by regulatory requirements. We cannot, therefore, always give a simple answer when asked how much of what we spend is for pollution prevention.

Looking at capital expenditure another way, obsolescence is not only a physical consideration, it is a subjective decision made sometimes from concern for environmental impact.

CIC is presently constructing its fourth installation of oxygen delignification and expanded

chlorine dioxide substitution equipment. Looking back on our first dioxide installation in 1985, it was purely for pollution prevention. In fact, it was a classic instance of a trade-off between an in-process change versus an end-of-pipe treatment. We chose in-process, not because it was cheaper, but because it minimized the environmental impact. CIC's move to chlorine dioxide substitution in excess of 50 percent has been driven by subjective judgments and by the desire to minimize potential environmental burden. We're in compliance without it, but we're also at a point in our modernization and expansion programs where it makes sound business sense to do it.

The chlorine dioxide substitution meets the criteria for cost, quality, competitiveness, and environmental integrity.

Research is focusing more today on process control and the ability to minimize process variations that cause environmental upsets. So, in addition to installing new technology, we need to give credit to the pollution prevention that comes from the most stable modern processes. Control rooms are testimony to the industry's commitment to control the potential sources of pollution. In respect to process control technology, today's mill employees are better trained than ever before. They understand the environmental, health, and safety consequences of what they do. They — and we — understand more because of developments in scientific research. The changes we have made have been driven by good science. Further changes must be made from the same solid scientific base if we are to avoid the pitfalls associated with perception-driven decisions.

Pollution prevention is no longer just an environmental consideration. It is a competitive issue — competitive not only from a manufacturing standpoint, but also from our customers and consumers' viewpoints. In addition, regulators and legislators are involved. The involvement of everyone is laudable; it also has risk. If there is no common set of facts, the possibility exists for subjective perceptions and manipulations. These, however, must be avoided. I strongly urge, and I think the industry strongly urges, that the worldwide competitive marketplace be allowed to function without interference.

Corporate Versus Societal Perspectives on Pollution Prevention Benefits and Total Cost Assessment

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Today, numerous forces are encouraging companies to shift from pollution control to prevention-oriented strategies. Prominent among these are liability under the Federal Superfund Act, public concerns with environmental degradation, increasingly stringent pollution disclosure requirements, and widely publicized industrial accidents in the United States and abroad. Despite these and other pressures, most firms have been slow to move away from traditional end-of-pipe strategies toward more prevention-oriented practices.

If, as many argue, pollution prevention pays, what accounts for this slow pace of change? If prevention investments are, in fact, in the self-interest of the firm, what accounts for the continuing reluctance to move aggressively toward a more preventative mode? And why, in light of the publicized benefits of pollution prevention, do firms, even large sophisticated ones, continue to be surprised when prevention-oriented projects produce attractive financial rewards to the firm?

Barriers to Pollution Prevention Within the Firm

The explanation for this apparent contradiction seems to be twofold. First, the organizational structure and behavior of firms inhibit pollution prevention projects from entering the capital budgeting process from the outset, thereby precluding altogether these alternatives from consideration by the firm. Second, once prevention investments are included in the capital budgeting process, they may still fail to compete successfully with other projects for limited capital dollars owing to inadequacies in standard profitability analysis techniques. Both factors contribute to a sluggish pace of investment in industrial pollution prevention. The focus of this presentation is the second factor, barriers within the capital budgeting process.

Capital budgeting is the development of a plan for capital spending over a defined period of time. The capital budgeting process includes the following activities: a search for profitable investment proposals, investigating engineering and marketing aspects of proposals to predict the outcome of the investment, and economic analyses to determine the profitability of the proposals. The size of a capital budget is generally based on estimates of future sales, costs, production, research and development (R&D) needs, and the availability of capital.

What are the special features of prevention projects that defy conventional profitability analysis procedures? When "environmental costs and savings" (e.g., waste management, regulatory compliance, future liability costs) are introduced into project analysis, certain limitations in traditional methods immediately surface. The source of these limitations lies in the uncertainties of environmental costs themselves, namely: What are they? How large are they? When will they occur?

For all of these questions, the degree of uncertainty can be high owing to two conditions: the

complexity of assessing risks associated with the use, transport, and exposure to hazardous substances; and rapidly changing regulations and shifts in judicial decisions that define and continually alter costs. Traditional project profitability analysis is not well equipped to handle the high degree of uncertainty and flux these two conditions create.

Total Cost Assessment

Total Cost Assessment (TCA) is an alternative approach to profitability analysis of prevention investments. TCA differs from conventional project analysis in several key ways. It uses expanded cost and savings inventories, a long time horizon, long-term profitability indicators, and it properly allocates environmental costs to processes or product lines within the company's cost accounting system.

Expanded Cost and Savings Inventory

Conventional cost analysis practices generally include only the capital costs directly associated with the investment, and any obvious operations costs and savings such as waste disposal and labor. TCA considers a broader range of costs and savings.

Typically, it includes direct costs such as capital expenditures — buildings equipment, utility connections, and equipment installation project engineering; and operation and maintenance expenses/revenues — raw materials, labor, waste disposal, utilities (energy, water, sewerage), and value of recovered material. Indirect or hidden costs, which include compliance costs — permitting, reporting, monitoring, and manifesting insurance; on-site waste management; and operation of on-site pollution control equipment. These costs are indirect or hidden in the sense that they are either allocated to overhead (rather than their source in the production process or product), or they are omitted altogether from the project's financial analysis. Liability costs, including penalties and fines, personal injury and property damage, and natural resource damages, must be considered.

Liability costs stem from penalties and fines for noncompliance, and legal claims, awards, settlements for remedial action, personal injury and property damage due to routine or accidental hazardous releases under the Comprehensive Emergency Response Compensation and Liability Act of 1980 (also called Superfund). This program holds companies financially responsible for environmental damage caused by previous waste disposal and management practices.

■ **The Effects of Pollution Prevention on Liability Costs.** A pollution prevention project by definition reduces or eliminates potential liability costs by reducing or eliminating the source of the hazard from the production process. One method described in the next section provides a procedure for estimating these potential costs, the year in which they will occur, and a method of incorporating them into financial calculations. In this way, liability is treated in the same way as conventional capital and operating costs. However, liability costs are by nature difficult to estimate and to locate in the life cycle of a project. By including estimates of future liability directly into a financial evaluation, the analyst introduces considerable uncertainty that top management may be unaccustomed, or unwilling, to accept as part of a project justification.

Firms currently use several approaches to considering liability costs in project analysis. For example, in the narrative accompanying a profitability calculation, a firm may include a calculated estimate of liability reduction, cite a penalty or settlement that may be avoided (based on a claim against a similar company using a similar process), or qualitatively indicate without attaching dollar value the reduced liability risk associated with the pollution prevention project. Some firms have chosen to loosen the financial performance requirements (e.g., raising the required payback period from three to four years, or lowering the required internal rate of return from 15 to 10 percent) of the project to account for liability reduction (U.S. Environ. Prot. Agency, 1988).

For publicly traded companies, liability estimation is controversial because the Securities and Exchange Commission requires firms to report liabilities to stockholders and accrue assets to cover these future costs. Also, a liability estimate may be damaging to a firm if it is made public in a legal proceeding. For all these reasons, if a firm considers liability costs in any form in project analysis, it normally exercises substantial caution in assigning a quantitative estimate of liability to a specific investment. Less tangible benefits of TCA are increased revenue from enhanced product quality and company image, reduced health maintenance costs from improved employee health, and increased productivity from improved employee relations.

These benefits, like liability, are difficult to predict and estimate. A TCA analyst may find a qualitative analysis more appropriate and saleable to management.

Expanded Time Horizon

A second feature of a TCA evaluation is its longer time horizon, usually 10 or more years, to capture certain costs and savings from pollution prevention

that take many years to materialize. Conventional project cost analysis, on the other hand, often confines costs and savings to a five- to ten-year period — a time horizon unlikely to capture the very cost and benefits that TCA is designed to track. The willingness of firms to extend the time horizon varies with their size, structure, capital, and competition from other investments.

Long-term Financial Indicators

To consistently provide corporate decisionmakers with accurate and comparable project financial assessments for capital budgeting, the financial indicators must meet at least two criteria: they must consider all cash flows (positive and negative) over the life of the project; and they must consider the time value of money. The Net Present Value (NPV), Internal Rate of Return (IRR), and Profitability Indicator (PI) methods meet both these criteria. The NPV method is preferred when projects are competing against each other for limited resources because there are certain conditions under which the IRR or PI methods fail to identify the most advantageous project. The payback method, commonly used by small companies, meets neither criteria.

The Cost Accounting System

A firm's cost accounting system is used to track and allocate production costs to a product or process line, principally for operational budgeting and pricing. When costs for waste management, regulatory compliance, and pollution control are properly allocated to processes or product lines, the cost accounting system provides a rich source of data for TCA. For purposes of investment analysis, the optimal cost accounting system should allocate all costs to the process responsible for their creation. Waste disposal costs, for example, often appear in overhead accounts, while a process or product allocation would assign such costs to an activity or component of the manufacturing process.

Costs should be allocated to reflect how costs are actually incurred. For example, waste disposal costs in some companies are allocated across operating centers — administrative, research and development, and manufacturing — on the basis of floor space rather than on the quantity and type of waste generated by each. This impedes a rigorous estimation of the financial benefits of reduced waste generation. Thus, effective cost accounting is critical to directing management attention to the sources of waste generation and the benefits of changing current waste management practices.

Case Studies of Total Cost Assessment in the Pulp and Paper Industry

A major source of industrial pollution, the pulp and paper sector provides a context for examining the usefulness of TCA. Historically, environmental regulation of the industry has focused on reduction of biological oxygen demand (BOD) and total suspended solids (TSS) in water effluent, and particulates, sulfur dioxide, and organic sulfur compounds in air. Reductions of these pollutants have been achieved principally through end-of-pipe controls.

Nonetheless, pollution prevention is by no means a new concept to pulp and paper firms. In-plant recovery and reuse of pulping chemicals are integral parts of the kraft pulping process. Other preventative measures include in-plant fiber and water recovery and reuse in the paper mill, countercurrent washing in the pulp mill, and dry wood debarking. These technologies have been widely implemented to reduce pollution generation and to reduce raw material and energy costs. Current environmental regulation of toxic air and water pollutants, toxic constituents in mill sludge, and pulp mill effluent standards for foam, odor, and color are posing new challenges to pulp and paper firms. Meeting many of these regulations will require materials and process changes rather than traditional end-of-pipe controls.

In a compliance context, a mill's choice between an end-of-pipe or a prevention strategy will depend heavily on the comparative economics of these options. This is true even when the firm expects a net loss on its investment. Unlike most end-of-pipe technologies, pollution prevention projects tend to reduce operating costs by reducing waste generation and avoiding compliance requirements and pollution-related liabilities. In addition, investments in pollution prevention may increase revenue by improving product or corporate image. Including these indirect and less tangible savings in the financial analysis of projects may enhance the estimated profitability (or reduce the estimated cost) of the prevention strategy and may be decisive in selecting a prevention versus an end-of-pipe option. It is at this decision point that TCA can play a role in improving the financial picture of a pollution prevention investment and enhance its competitiveness with pollution control projects. TCA techniques also can improve the projected financial performance of discretionary pollution prevention projects, thereby increasing their ability to compete for limited capital resources.

To assess how TCA works in practice, we worked in close collaboration with the staff of two mills to analyze the profitability of two pollution prevention projects (U.S. Environ. Prot. Agency, 1991). The first is a conversion from solvent/heavy metal paper coating to aqueous/heavy metal-free coating at a paper coating mill. This investment would substantially reduce solvent and heavy metal usage, volatile organic compounds (VOC) emissions, and hazardous waste generation. The second is a white water and fiber recovery and reuse project at a coated fine paper mill. This investment would permit fiber, filler, and water reuse on two paper machines at all times, thereby conserving raw materials and reducing water use, wastewater generation, and energy use for fresh and wastewater pumping and freshwater heating. Table 1 provides an overview of these projects.

Table 1.—Overview of Total Cost Assessment case studies.

COATING CONVERSION PROJECT

Paper Coating Mill

Current Conditions:
- Pigmented base coatings contain:
  - Solvents
  - Heavy metals — lead, chromium, cadmium

Problems:
- Volatile organic compounds (VOC) emissions
- Hazardous wastes generated containing solvent and heavy metals
- Heavy metals in product

Proposed Project:
- Convert to aqueous, heavy metal-free base coating

Benefits:
1. Reduce/eliminate solvent and heavy metal use
2. Reduce VOC emissions
3. Reduce hazardouse waste generation

WATER AND FIBER RECOVERY PROJECT

Coated Fine Paper Mill, 200 TONS PER DAY

Current Conditions:
- Two paper machines share one white water system
- One machine has a dedicated saveall
- Machines produce a variety of grades (acid, neutral, alkaline)

Problems:
- White water from two machines often incompatible; therefore, whitewater must be sewered — loss of fiber, filler, water

Proposed Solution:
1. Separate white water systems, and
2. Install dedicated saveall for second machine

Benefits:
1. Recovery and reuse of fiber and filler
2. Recovery and reuse of water:
   - Reduced freshwater pumping and heating
   - Reduced wastewater pumping and treatment

For both projects, we compared the company's financial analysis to TCA analyses of the same project, in which a full accounting was made for less tangible, longer term, and indirect costs and savings. In the case of the coating conversion project, the paper coating firm omitted all nondisposal waste management costs, utilities (energy, water, and sewerage), solvent recovery, and regulatory compliance costs from its analyses of the aqueous conversion project. The firm also omitted several costs associated with the storage needs and shorter shelf life of aqueous coatings, namely a steam heating system for the coating storage shed, lost raw material value, and the cost to dispose of spoiled coating (see Table 2).

According to our collaborator at the second mill, a financial analysis of the white water/fiber recovery project would not include energy savings associated with reduced fresh and wastewater pumping and treatment and freshwater heating. These energy savings, which are included in the TCA, represent a substantial benefit of the project. Their omission in a conventional financial analysis would have dramatically underestimated the profitability of the investment.

In these case studies we focused on two general forms of future liability costs: liability from personal injury or property damage (e.g., Superfund liability stemming from a leaking landfill) and penalties and fines for violation of environmental regulations. The paper coating mill did not include an estimate of avoided future liability costs from reduced hazardous waste disposal in its financial analyses. It did, however, allude to this benefit in a qualitative way in an appropriations request: ". . . major reductions in levels of fugitive emissions, and amounts of solid hazardous waste going to landfill, are very positive from a regulatory and community standpoint." The TCA developed for this project includes an estimate of avoided future liability made using a methodology contained in General Electric's *Financial Analysis of Waste Management Alternatives* (1987). The mill sends its coating waste to an incinerator, so this risk-based methodology produces a relatively low estimate of $35,000 in total avoided liability for the project. Since Project 1 does not involve hazardous materials or waste, neither the company analysis nor the TCA contains a future liability estimate.

Neither the company analyses nor TCAs contain estimates of less tangible benefits. In the case of the coating conversion project, the coated paper product is sold domestically on the basis of cost, visual appearance, and performance durability to book publishers and other intermediate product

Table 2.—Overview of cost inclusion by company and Total Cost Assessment.

	COATING CONVERSION		WATER/FIBER RECOVERY	
	COMPANY	TCA	COMPANY	TCA
CAPITAL COSTS				
Purchased equipment	X	X	X	X
Materials (e.g., pipe, electricity)			X	X
Utility systems			X	X
Site preparation			X	X
Installation			X	X
Engineering/contractor	X	X	X	X
Start-up/training	X	X		
Contingency			X	X
OPERATING COSTS				
*Direct Costs:**				
Raw materials/supplies	P	X	X	X
Waste disposal	P	X		
Labor	X	X	X	X
*Indirect Costs:**				
Waste Management				
Hauling	X	X		
Storage		X		
Handling		X		
Waste-end fees/taxes		X		
Utilities				
Energy		X	P	X
Water		X		X
Sewerage (publicly owned treatment works)		X	X	X
Pollution control/solvent recovery		X		
Regulatory compliance				
Future liability		X		

X = cost(s) included; P = cost(s) partially included.
* The term "direct costs" means costs that are typically allocated to a product or process (i.e., not charged to an overhead account) *and* that are typically included in financial statements. In this table, "indirect costs" mean costs that are typically charged to an overhead account *and* typically not included in the project financial analysis.

manufacturers. Although the company expects some quality improvements using aqueous coating, it does not anticipate an increase in market value. Therefore, it expects no increase in domestic sales as a result of the conversion to the aqueous/heavy metal-free coating. The company hopes to improve its competitive advantage in the European market if the European Community implements lead-free packaging standards as expected; however, it would not speculate on the potential revenue effects associated with increased European market share, though clearly they could be very substantial.

The coated/fine paper mill does not expect an increase in market share or product value from its white water/fiber reuse project. Both mills are manufacturers of intermediate, rather than consumer, products and cannot directly market their products on the basis of environmental performance in the way that a consumer products company can and does.

The comparative analyses for each project yield substantially different results (see Tables 3 and 4). Impressive results are produced for the aqueous conversion investment. The net present value for this $0.6 million capital expenditure shifts from $0.1 million to $0.2 million in the company versus TCA analyses, respectively; the internal rate of return shifts from 16 percent to 27 percent; and simple payback drops from 5.3 to 3.0 years. Similarly, for the fiber/water recovery investment, the net present value for this $1.7 million capital expenditure increases from minus $0.6 million in the company analysis to $1.8 million using a TCA approach; the internal rate of return increases from 6 percent to 36 percent; and the simple payback of 11.4 years decreases to 2.0 years.

Analysis of a limited sample of two projects does not suggest that more comprehensive treatment of project costs and savings necessarily yields higher projected profitability for prevention investments. Much depends on the project's original capital cost, the completeness of the company analysis, and indirect and less tangible benefits' magnitude and timing. TCA is equally likely to turn up additional costs as additional savings, potentially diminishing the appeal of prevention investments. Moreover, the effort expended in preparing

Table 3.—Summary of financial data for coating conversion project.

	COMPANY ANALYSIS	TOTAL COST ASSESSMENT
Total capital costs	$623,809	$653,809
Annual savings (BIT)*	$118,112	$216,874
Financial Indicators:		
Net present value (years 1–15)	$13,932	$428,040
Internal rate of return (years 1–15)	16%	27%
Simple payback (years)	5.3	3.0

* Annual operating cash flow before interest and taxes.

Table 4.—Summary of financial data for white water and fiber recovery project.

	COMPANY ANALYSIS	TOTAL COST ASSESSMENT
Total capital costs	$1,329,000	$1,329,820
Annual savings (BIT)*	$ 116,245	$ 658,415
Financial Indicators:		
Net present value (years 1–15)	($587,346)	$1,808,384
Internal rate of return (years 1–15)	6%	36%
Simple payback (years)	11.4	2.0

* Annual operating cash flow before interest and taxes.

the TCA analysis, though partially attributable to startup costs of any new management practice, is substantial enough to make even large firms wary of adopting such an approach for all projects competing for capital resources.

Within the limitations of our study, however, it is clear that TCA can serve as a valuable tool for translating discretionary judgments into concrete dollar values during the capital budgeting process. Insofar as pollution prevention projects produce less tangible and indirect costs and benefits, TCA equips managers to develop a more precise estimation of the real financial returns. Though TCA does not ensure an attractive profitability level for prevention projects, the cost characteristics of such projects suggest that their financial performance in general will be enhanced by TCA. This is especially true for industrial prevention projects that are materials and process-focused, that is, well upstream in the production process. Over the longer term, TCA can serve as a substantial force in recasting the "must-do" and "inherent loser" image of environmental projects into a more positive, profit-adding, and market-expanding image.

As a final note, what is financially optimal for the firm, of course, is not necessarily optimal from a social cost standpoint. In this sense, TCA is no substitute for life cycle analysis (LCA), in which the choice of a material input or the manufacture of a product is assessed for its full societal costs, whether such costs fall within or outside the purview of the firm.

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Meeting the Challenge of "No Effect" Pulping and Bleaching

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Environment and Technology
Weyerhaeuser Company
Tacoma, Washington

Founded in 1900, Weyerhaeuser is one of the oldest and largest forest products companies in North America. The company has four main sectors — Pulp and Paper, Solid Wood, Timberlands, and Real Estate. I am part of the Pulp and Paper sector, which has several operating divisions — Market Pulp and Recycled Fibers, Fine Paper, Newsprint and Bleached Board, and Containerboard Packaging.

The Weyerhaeuser Company is the world's largest producer of softwood lumber and one of North America's largest exporters in the pulp and paper industry. Overall the Weyerhaeuser Company has

- 5.6 million acres of timberlands,
- 12 primary pulp and paper facilities in the United States and Canada, and
- 8 facilities that produce bleached pulp and paper products.

Weyerhaeuser's production capacity has reached 6 million tons per year of pulp and paper, and we manage 1.8 million tons per year of recycled fiber.

Weyerhaeuser also has a long history of environmental accomplishments. In 1941, we dedicated America's first tree farm, and in 1967, we appointed our first Director of Environmental Affairs. In the last three decades, the company has marked the following milestones:

- **1971** — adopted formal, companywide environmental policy
- **1974** — began recycling program
- **1979** — completed installation of secondary waste treatment systems at all primary facilities
- **1986** — planted our 2 billionth seedling on company land
- **1987** — launched companywide ongoing environmental auditing program
- **1991** — participation in EPA pollution prevention effort (33/50 program)
- **1992** — joined the Global Environmental Management Initiative (GEMI)

The goal of "no effect" pulping and bleaching involves more than media-specific pollution prevention. We must ensure that the total pulping and bleaching process prevents pollution, and we must balance our emissions to air, water, and land to minimize their overall environmental impact. We must practice waste minimization and make continuous improvements in health and safety methods.

The pulping and bleaching processes are part of an interconnected system. Changes in one process often affect the performance of other processes. Enormous resource commitments of time and capital are essential for most changes.

The "No Effect" Vision

Our goal is to eliminate environmental impacts while maintaining or improving quality, productivity, and economic competitiveness.

The evolution toward "no effect" pulping and bleaching systems is constrained by customer quality demands, regulatory expectations, technological evolution, high capital costs, and industry competitiveness. We will review each of these constraints in more detail.

Customers always want the best quality products at the lowest possible price and with the best possible service. They want value. The customer, not the producer, defines quality and we must never forget that demand drives supply.

A pulp and paper mill must deal with customer expectations and regulatory expectations. A multitude of increasing regulatory expectations affects every facility today.

Figure 1 looks at the range of issues that need to be addressed as we move toward "no effect" mill operations. Unless regulatory programs are properly focused and entaligned, they will actually divert our resources from achieving the final vision.

Overview of Prevention Technologies

Pollution prevention is not new to kraft pulping or our industry. Advances in technology began in the 1940s and led to cleaner and tighter operations. Two advances in the 1940s were the introduction of chlorine dioxide substitution in multistage bleaching and continuous digesters; the 1970s gave us low-odor boilers, Rapson-Reeve bleach plant effluent recycling, oxygen delignification (bleaching), extraction-stage oxygen, and displacement bleaching. High-efficiency washers and extended delignification were implemented in the 1980s; and finally, in the 1990s, ozone bleaching is being pursued.

Weyerhaeuser has been a leader in developing many pollution prevention technologies. Table 1 lists a selection of Weyerhaeuser patents or procedures in chronological order. Note that most of these technologies were brought to full-scale implementation.

Significant advances in pulping and washing technologies have allowed for more efficient lignin removal in the digester system, resulting in a greatly reduced need for bleaching and bleaching chemicals. In addition, there have been significant changes in bleaching technologies through time. The evolution of state-of-the-art bleaching processes has had a dramatic impact on the amount of adsorbable organic halogens (AOX) found in bleach plant effluents (see Fig. 2).

AOX is a gross measure of chlorinated organics and one measure of general loading to the environment. To date, we have found no correlation between AOX and toxicity. We need to be cautious about drawing broader conclusions than the measurement technique warrants.

Bleaching is a multiple-step operation, not simply the use of chlorine or oxygen. Multiple stages are used to improve pulp quality as well as reduce the total chemical usage.

Ingemar Croon of Croon Consult in Stockholm, Sweden, has developed a model of worldwide bleaching chemical use (see Fig. 3) based on the evolution of technologies in the pulp and paper industry. Weyerhaeuser's bleaching chemical use reflects similar trends, and is also customer- and technology-driven (see Fig. 4).

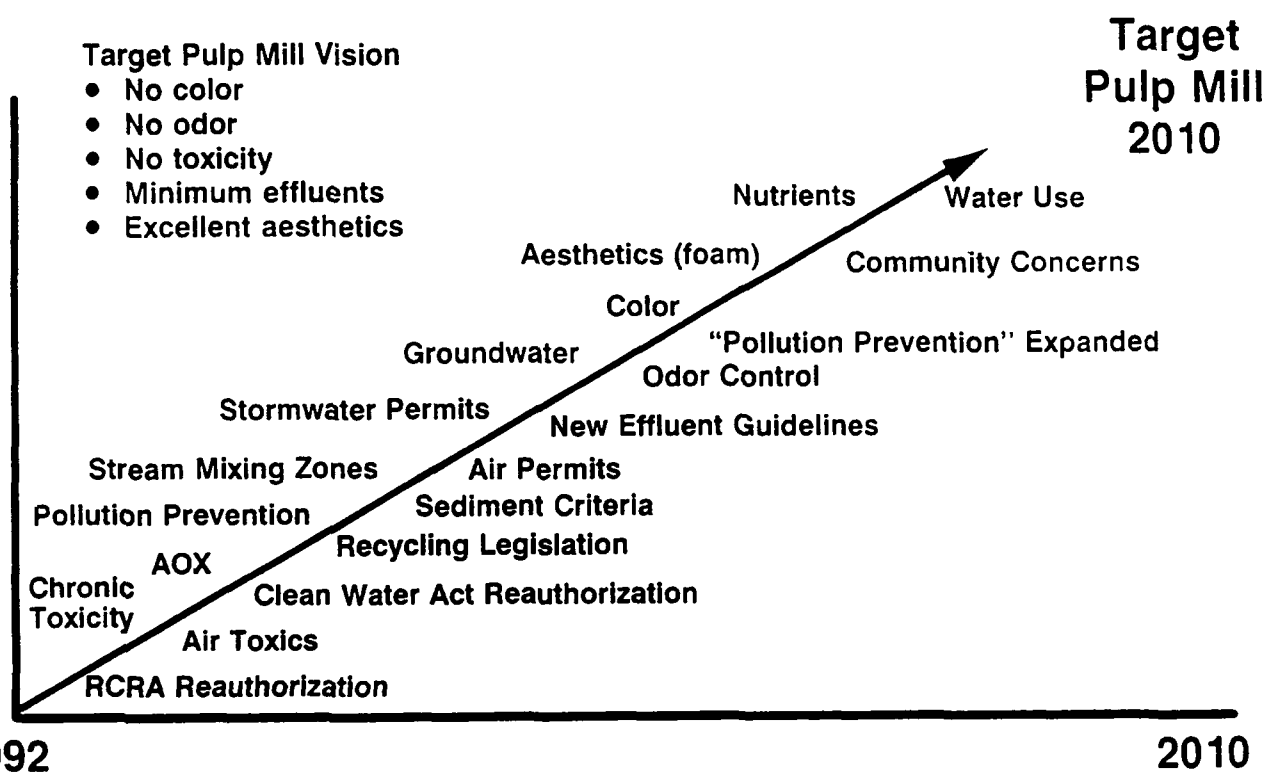


Figure 1.—Regulatory expectations.

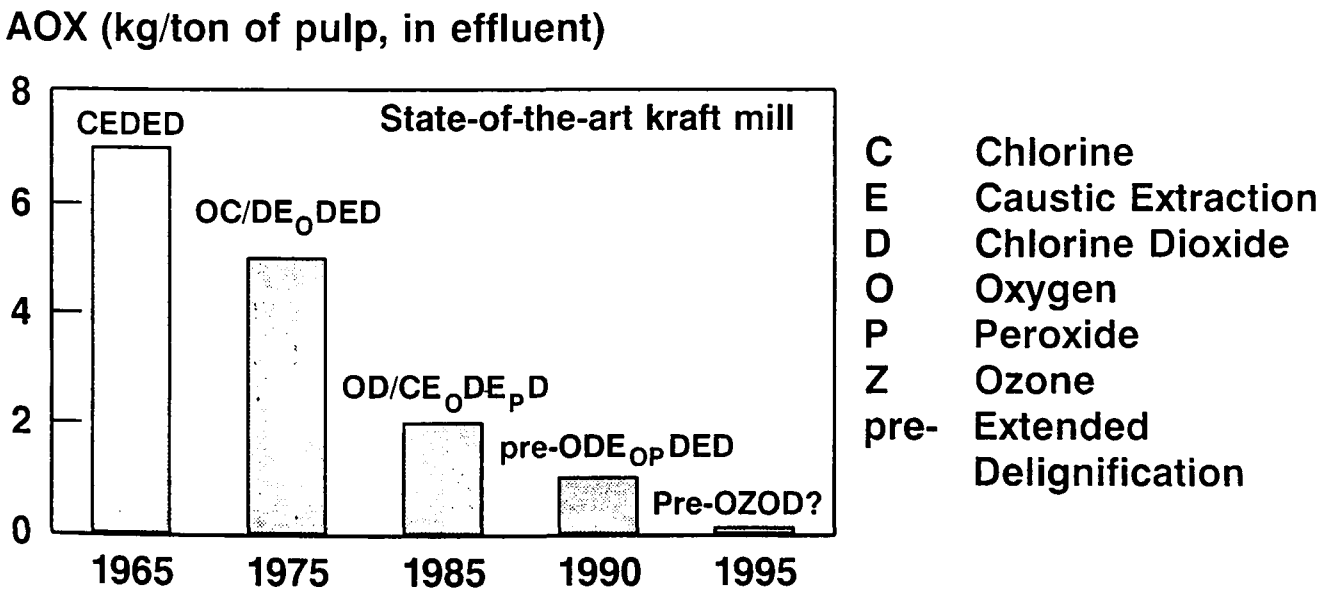
Table 1.—Weyerhaeuser patents or procedures.

YEAR	TECHNOLOGY	PATENTED	TRIAL/PILOT PROGRAM	FULLY IMPLEMENTED
1948	Developed magnesium-based sulfite process	X		X
1954	Developed vaposphere to reduce odor	X		X
1962	Black liquor oxidation to reduce TRS			X
1968	Acetic acid recovery from sulfite condensate	X		X
	Red liquor stripping to remove SO_2			X
1970	Caustic scrubbing of chlorination washer vent gas	X		X
1972	Kraft condensate stripping	X		X
1973	Soda-oxygen pulping			X
	Vapor phase bleaching		X	
	Rapson-Reeve beach plant effluent recovery		X	
1974	Dry scrubber for hog fuel boilers	X		X
	Displacement bleaching			X
1981	Large-scale ozone bleaching pilot plant	X	X	
1991	Artificial marsh			X

Technologies take time to develop and implement. As an example, oxygen bleaching lab experiments were done in the early 1950s and the first pilot plant was in 1967 — long before the current cry for chlorine-free processes and products. The evolution of oxygen bleaching technology clearly illustrates that extended periods of time are needed to develop, prove, and implement technologies on a large scale. In 1973, Weyerhaeuser was one of the first to install an oxygen system. It was not until the advent of medium consistency oxygen bleaching, 10 years after the first commercial installations, that the technology gained universal acceptance (see Fig. 5). Weyerhaeuser has three oxygen bleaching systems in place at this time and three more will be coming on line in the near future.

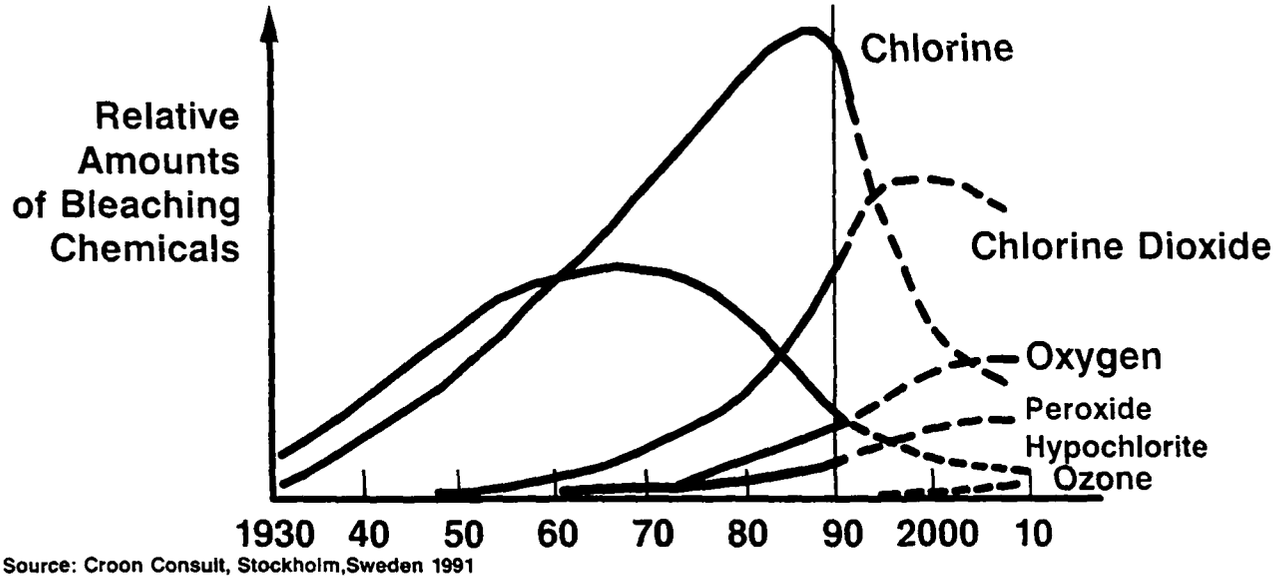
Weyerhaeuser is planning major modernizations at several of its pulp and paper facilities. As a result of these modernizations and because of customer requirements, the availability of proven technologies, and their alignment with the goal of closed-loop systems, Weyerhaeuser expects to reduce the use of elemental chlorine for bleaching by over 95 percent by 1996 (see Fig. 6). Although high environmental standards are already being met by well-run bleached kraft mills with secondary treatment, modernized operations will make our overall environmental performance even better.

In addition, Weyerhaeuser is committed to the development of new and better technologies that can continue to move us toward the optimal goal of



Note: AOX does not correlate with toxicity

Figure 2.—Reducing bleaching effluent.



Source: Croon Consult, Stockholm,Sweden 1991

Figure 3.—Bleaching chemical use — a worldwide perspective.

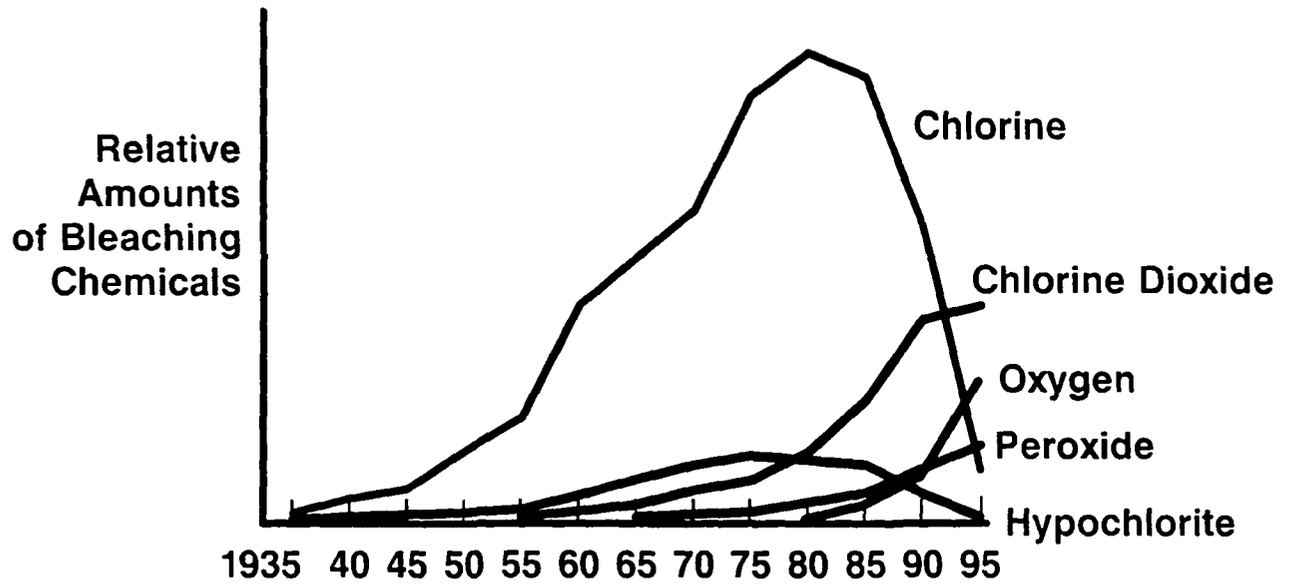


Figure 4.—Weyerhaeuser bleaching chemical usage.

a "no effect" mill. Weyerhaeuser has already reduced dioxin formation by more than 97 percent since 1987-88, when trace quantities were first detected in pulp mill effluents. Dioxin is currently nondetectable in all of our bleached pulp mill effluents. Our concern now is contamination from external sources rather than generation of dioxin within our processes.

As we move toward "no effect" mills, all effluents will be reduced dramatically. Weyerhaeuser's data illustrate the accomplishments achieved to date and also suggest trends for the future (see Fig. 7). It should be noted that most of our early efforts were directed to reducing conventional pollutants. One key assumption is that elemental chlorine must be removed from the bleaching process so that we can close up the process streams and recycle them to the recovery boiler. This process will allow us to eliminate the small quantities of organic material currently going to treatment facilities and to recover additional pulping chemicals. Elemental chlorine in the process forms chloride ions, which cause corrosion and decreased boiler efficiency when recycled.

High Capital Costs

A major constraint to upgrading facilities is the staggering cost of pulp and papermaking equipment. The paper industry is the most capital-intensive industry in North America, more than metals, chemicals, or petroleum. As a percent of sales, the paper industry spends twice the average of all U.S. industry on new plants and equipment. A process change that on the surface sounds simple, such as incorporating oxygen bleaching, can cost in the

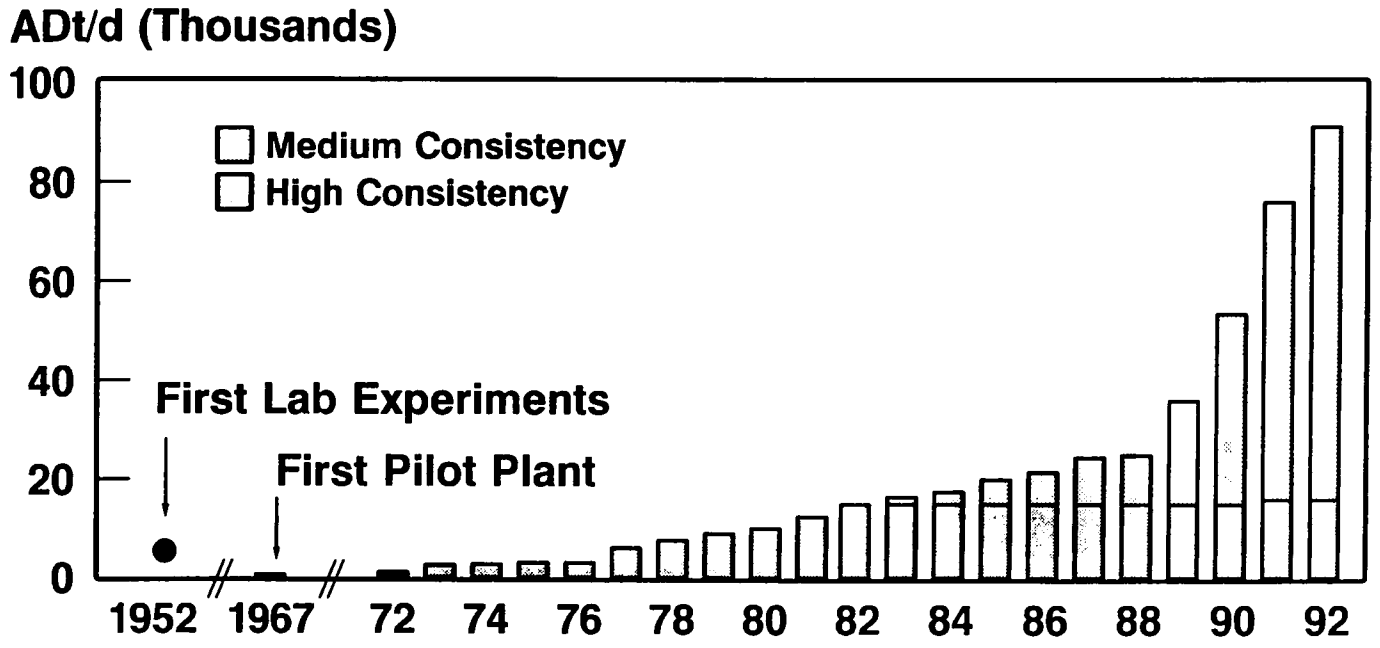


Figure 5.—Worldwide oxygen delignification. Source: Jaakko Poyry, 1991

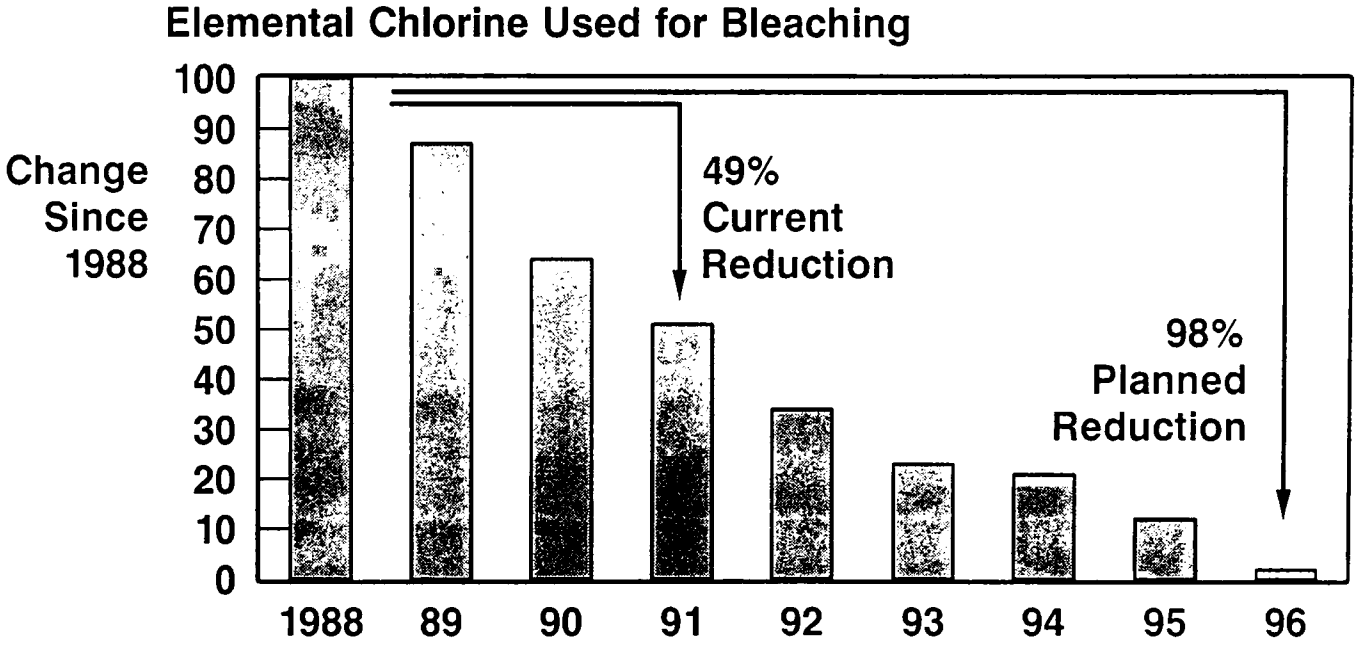


Figure 6.—Chlorine bleaching at Weyerhaeuser.

range of $30 million and take up to three years from concept, approval, and design to installation and start-up. In addition, costly or negative side effects, such as additional loading to the recovery boiler, must be taken into account. Customer reaction to changes in pulp and paper quality is another important consideration.

Limited capital must be allocated between competing priorities. Is it better to expand recycling capacity or modify bleaching processes? In the pulp and paper industry, it appears, companies must do both. This competition for capital forces many companies to set priorities among conflicting stakeholder needs. Weyerhaeuser is more than doubling its recycled fiber usage every five years. We strongly support the industry recovery goal of 40 percent by 1995. In fact, with three active projects coming on line in the near future, and other projects being considered, Weyerhaeuser will play a strong role in helping the industry achieve its overall objective (see Fig. 8).

Conclusion

Since no two plants are the same, mandatory inflexible standards can siphon scarce capital away from achieving environmental goals. Piecemeal and conflicting regulations can sidetrack or delay

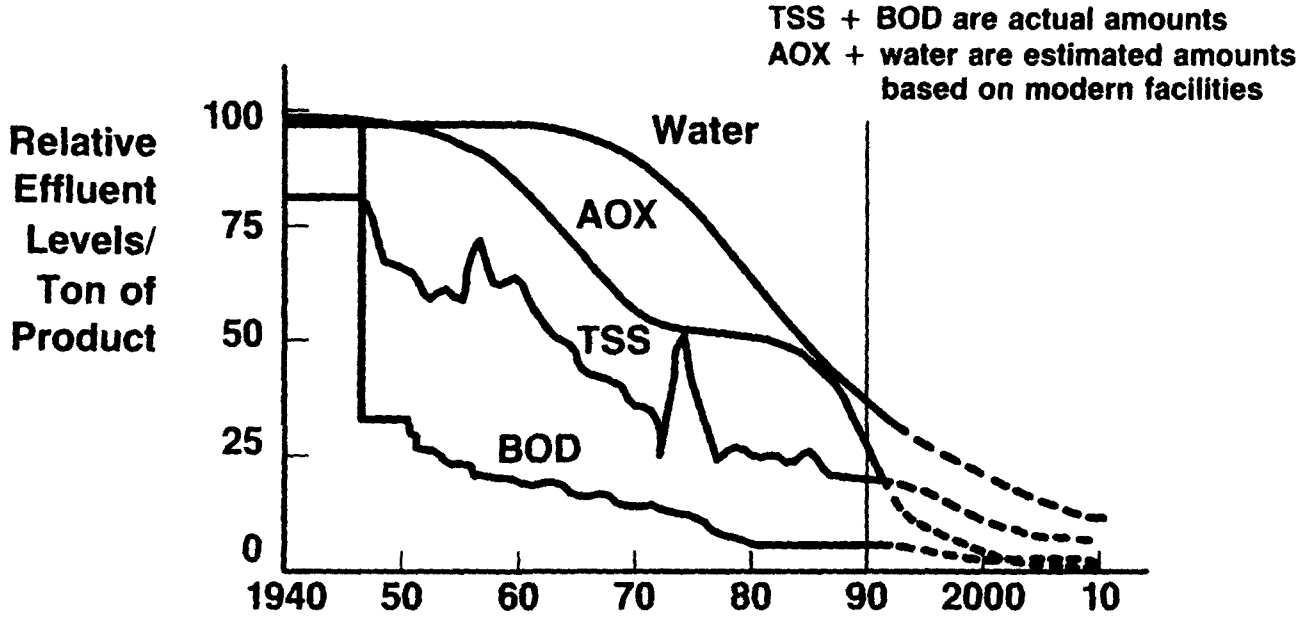


Figure 7.—Weyerhaeuser effluent reduction.

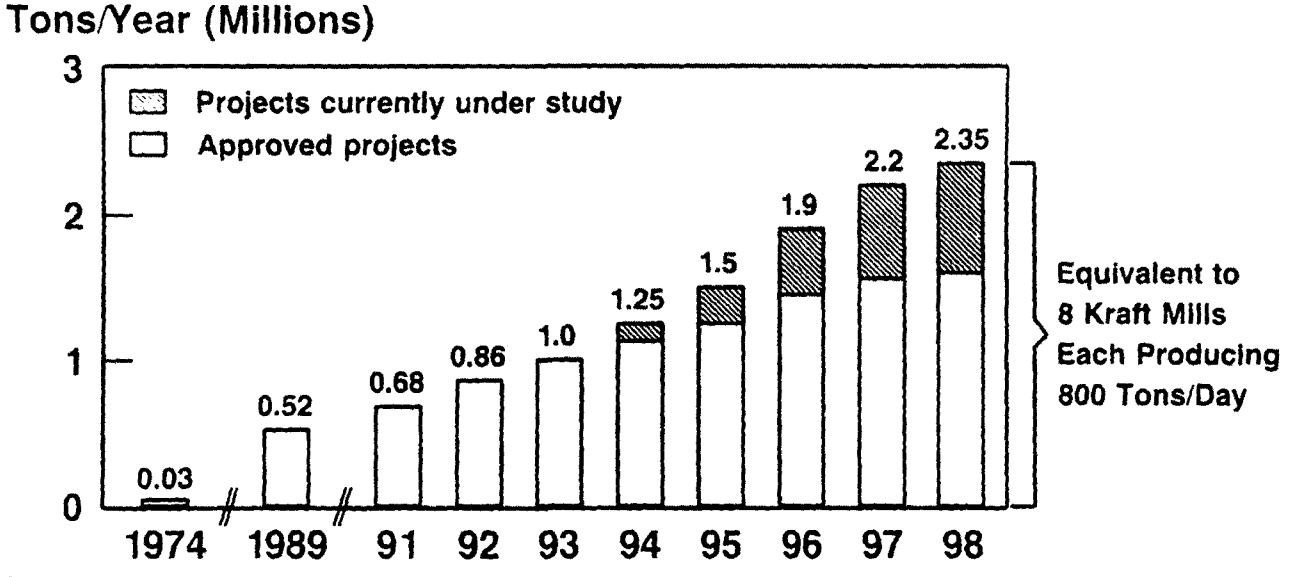


Figure 8.—Weyerhaeuser recycled fiber usage.

investments in line with the "no effect" vision. Government can do the following to facilitate pollution prevention and the "no effect" vision:

- Keep regulations simple — complexity increases errors.
- Coordinate regulatory initiatives to assure wise capital investment in the long run.
- Maintain regulatory flexibility — the industry needs the ability to use a variety of process and treatment options to meet environmental requirements.
- Be aware of the global market — competition is worldwide.
- Support sound science and economics to ensure rational investments addressing real priorities.

Pulping and bleaching are a part of a cycle in the manufacturing of forest products. Our goal is to advance the whole cycle, focusing research, technology, and capital at the right time and in the right places to derive the optimum environmental benefit overall. "No effect" is the ultimate goal of the forest products industry. It should include sustainable forestry providing fiber and energy from pulpwood trees, sawdust, and forest residuals; energy self-sufficiency in pulp and paper production; closed cycle mills; the recycling of usable recovered fiber; the clean conversion of unusable recovered fiber to other uses, energy, or compost; and the return of ash and compost to the land. Weyerhaeuser's goal is nothing less.

Panel 1:
Pollution Prevention and Lifecycle Analysis

Question and Answer Session

■ **Gayle Coyer,** *National Wildlife Federation:* I think that some of the points that Monica Becker illustrates are very important and I would like to get reactions from Dick Diforio and Dick Erickson. How much do your companies consider pollution prevention versus pollution control? When you present us with statistics and figures on capital investment in pollution abatement, can you break those statistics down into how much goes into not creating or generating pollution in the first place versus pollution control once it has been created?

■ **Dick Erickson,** *Weyerhaeuser Company:* At this point, very little of our capital investment goes for end-of-pipe treatment. Nearly all capital is for pollution prevention. The problem is that when you are looking at capital investments on three major modernizations from 1940s technology, you're expecting quality, cost, and productivity benefits as well as pollution prevention, so we can't just look at one item. The toughest thing for us is looking at the liability side; five years ago, the liabilities people are facing now were unimaginable. What are the liabilities that we will face five years from now? So liability costs are the toughest ones to predict. But certainly we use pollution prevention calculations to estimate future operating costs and most of the money is for pollution prevention projects rather than pollution control.

■ **Richard Diforio,** *Champion International Corporation:* I would concur with Dick Erickson. In our case, we are involved in one major modernization, one major expansion, and we are about to embark on some other internal process changes. All of these have been driven by in-process considerations, not end-of-pipe considerations. If there is an end-of-pipe consideration in any of our investments, it could only be that we haven't found any reasonable way to take care of the problem within the process as we now perceive it. I suppose we could break it out in dollars and cents, or have that done internally. But I assure you that every engineer has as his or her principal objective to clean up the process as opposed to controlling pollution at the end. And I don't say that boastfully as far as Champion is concerned; I think this attitude is typical of the industry.

■ **Ray Chalk,** *World Bank:* I deal entirely in the developing world. I have just come back from China, where we made a major pollution improvement by installing a recovery boiler. I am very impressed with what Mr. Erickson had to say about the year 2010, and I would like to ask him and others how can we move faster in the developing world? What is it that moves your company? Is it regulation, cost savings, or the opportunity to be a good corporate citizen?

■ **Dick Erickson:** All of the above.

■ **Ray Chalk:** Is there a priority among them?

■ **Dick Erickson:** No, as I mentioned before we are making three major modernizations — at a huge sum for us. We are really looking at quality. First in mind comes the customer. If we don't have a customer, we don't exist. We have to ensure that the customer is taken care of. The quality of the product is second. It comes from an internal process control or process management. Cost

savings are the third major incentive; basically our modernizations are replacing 1940s technologies. So energy, chemicals, and our people resources must be used properly.

We have five pulp mills in one facility — we're going to one. So, of course, we want the in-process changes to reduce the environmental impacts — in air, water, and solid wastes. The key is technology management, and the technology that was developed in the 1950s and 1960s is now commercially available to us at the same end-cost. To modernize just casually is very difficult. If a mill modernized 10 years ago, it will have a difficult time to legitimize the huge investment necessary to make what is now only an incremental gain. For Weyerhaeuser, the gains are quite large.

■ **Richard Diforio:** There's no Silver bullet, and no one way to do it. I think you have to look at a site-specific situation, whether it's a country or a particular mill or process within the mill, then make your judgments about the best approach for that particular situation.

■ **Unidentified Speaker:** Give us an example. You said it is difficult or dangerous for an outsider to the company to use the results of lifecycle analysis. What did you mean by that statement?

■ **Frank Consoli,** *Scott Paper Company:* If I have an internal lifecycle assessment done at Scott and then I publish it to a client or other external user — or perhaps the Environmental Protection Agency (EPA) or someone else wanted to use it — it would be very difficult for these users to get the full embodiment of the study. Literally, when you do a lifecycle assessment, you end up with a desk full of numbers. And not only do you end up with a desk full of numbers, but behind each number is a data quality path that contains numerous assumptions and bits of information that went into developing the number. We just went on a month-long trek, for example, to find one number. This is very complex stuff, so to do it in a way that everyone can understand is tricky at best.

The second difficulty is that the impact assessment area is in its infancy. Inventory data alone are meaningless. I need to provide a framework of what the impacts are, and we are still in the process of trying to develop those kinds of methodologies. My point — and I know my view is shared by some people at EPA and the attorneys general — is that we are not quite sure yet whether lifecycle assessments are ready for prime time. That doesn't mean you can't use them. But in terms of saying this product is better than that product, or that from an environmental perspective this technology is superior to others; I have got to tell you, we are not yet ready for that and may never be.

The ABCs of Conventional Technologies Related to Pulping and Bleaching

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The purpose of this paper is to provide a brief overview of "conventional" pulping and bleaching technologies, with two objectives. First, I would like those who are not very familiar with the industry to gain an appreciation of the diversity and technical complexity of the various pulping and bleaching processes used by the industry. Second, I hope that this paper will set the stage for discussions of the new and modified technologies that subsequent authors will introduce.

Pulping Technologies

The manufacture of unbleached pulp begins with a raw material that has a complex microscopic structure. Figure 1 is a close-up view of a little block of pinewood showing one annual growth ring and part of another. The top surface is similar to what we would see if we looked at the end of a log with a powerful magnifier. The wood is made up of many hollow cells, each about a thousandth of an inch in diameter. The cells are elongated and arranged in parallel fashion. They are also quite rigid because they are impregnated with lignin, which is a rigid substance. In addition to imparting rigidity, lignin serves to cement the fibers together.

With regard to the chemical composition of wood, all we have to know for our present purposes is that it is made up of three substances, occurring in roughly equal proportions: cellulose, hemicellulose, and lignin. Cellulose consists of long, chainlike molecules that possess extremely high tensile strength. Cellulose is resistant, but not immune, to chemical attack and can be dissolved only with difficulty. Hemicellulose is somewhat similar in structure to cellulose but is more easily dissolved and not as strong. Lignin, as noted above, is the rigid, brittle, water-insoluble material that impregnates the cells and cements them together.

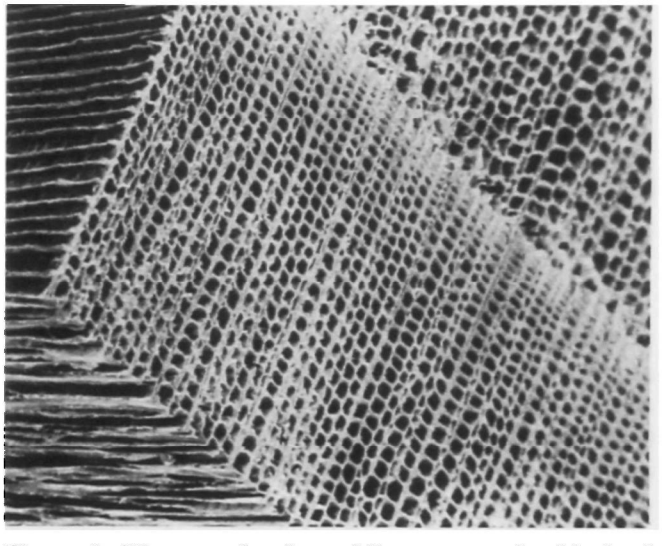

Figure 1.–Microscopic view of the corner of a block of pinewood.

Mechanical Pulping

Pulping may be defined as the separation of the wood cells from one another, after which they are referred to as fibers. Two of the many ways of doing this are mechanical pulping and chemical pulping. In mechanical pulping, the fibers are separated by simply tearing them apart — that is, by grinding up the wood. In chemical pulping, on the other hand, chemicals are used to dissolve the lignin; then the fibers are easily separated.

A major advantage of mechanical pulping is the high yield of fiber. Nearly all the wood is converted into product. The off-setting disadvantages are the substantial damage suffered by the fibers and the undesirable properties imparted to them by the remaining lignin. The result is relatively weak paper that easily turns yellow. You've seen that happen if you have ever left a newspaper out in the sun for more than a few minutes. As shown in Figure 2, mechanical pulps consist of straight, rigid, and inflexible fibers that have been damaged during separation. Separation is also incomplete, resulting in the occurrence of small broken bundles of unseparated cells.

Figure 2. –Microscopic view of mechanical pulp fibers.

There are many different mechanical pulping processes that are often referred to by their acronyms (Table 1). The first two on the list, SGW and PGW, use cylindrical grindstones to pulp logs; the others use disk refiners to pulp wood chips. In the case of thermomechanical pulp (TMP), the refiner is operated at high temperature and pressure to soften the lignin. TMP is now the dominant mechanical pulping process used in the United States. Note also that some of these processes use chemicals to soften the lignin. These chemithermomechanical pulp (CTMP) processes are part of a whole spectrum of processes bounded on the high-yield end by pure mechanical pulping and on the low-yield end by pure chemical pulping.

Chemical pulping avoids the disadvantages of mechanical pulping by removing most of the lignin before attempting to separate the fibers. As a result, the fibers suffer very little damage — they remain strong and intact. Subsequent bleaching to remove the residual lignin that remains after pulping gives lignin-free fibers that bond together to form very strong paper. A noticeable disadvantage is the low yield of pulp per ton of wood. This disadvantage, however, is largely offset by recovering the dissolved wood and using it to generate energy. If you look at a chemical pulp through a microscope (Fig. 3), you will readily see that the fibers are undamaged. Their bent and twisted configuration indicates that they are flexible and conformable. These last two properties enable the fibers to contact and bond to one another efficiently.

Table 1.–Some mechanical pulping processes and their acronyms.

SGW – Stone Groundwood Pulping
PGW – Pressurized Groundwood Pulping
RMP – Refiner Mechanical Pulping
CMP – Chemimechanical Pulping
TMP – Thermomechanical Pulping
CTMP – Chemithermomechanical Pulping
APMP, BCTMP, TCMP, etc.

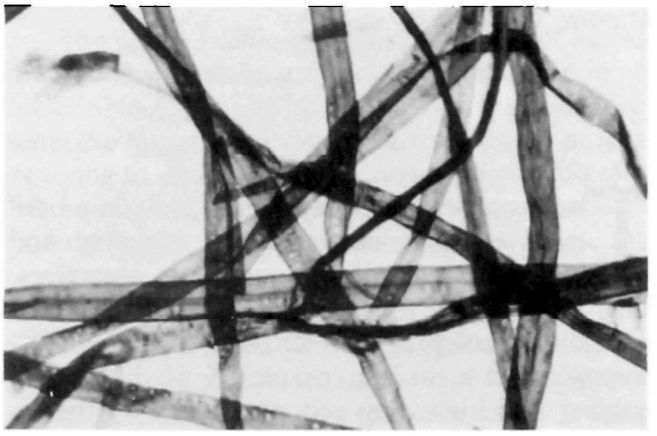

Figure 3.–Microscopic view of kraft pulp fibers.

A variety of chemical pulping processes are available, but kraft pulping is dominant in the United States and Canada. Kraft pulping was, however, preceded by the sulfite process, which used an acidic solution to dissolve the lignin. The most commonly used form of the sulfite process generated spent pulping liquor that could not be easily recovered; it was discharged instead to the receiving water. Replacing sulfite pulping with the kraft process ended this environmentally unsound practice because spent pulping liquor recycling is an intrinsic part of the kraft system. Other points worth noting here are that sulfite pulping produces weaker fibers that are easier to bleach than kraft fibers, and the kraft process is sometimes called the sulfate process and confused with the sulfite process. Because of the dominance of the kraft process in North America, I will restrict my remarks to this process for the balance of this presentation.

Bleaching Technologies

Bleaching is the chemical treatment of pulp fibers for one or several different purposes: (1) to increase the pulps' whiteness or brightness; (2) to improve

cleanliness by disintegrating or decolorizing contaminating particles, such as pieces of bark or unpulped fiber bundles; (3) to improve brightness stability by reducing the tendency of the bleached pulp to turn yellow; (4) to remove residual hemicellulose or resinous contaminants that are also known as extractives; and — not the least important — (5) to alter the physical properties of the pulp in ways required to achieve a particular use.

Most of these objectives are achieved by oxidizing and removing residual lignin from the fiber. Brightness, for example, is adversely affected only by residual lignin because cellulose and hemicellulose are virtually colorless. Since lignin removal is its major objective, bleaching can be considered an extension of the pulping process. Lignin, which comprises about one-quarter of the original wood, is largely removed in the pulping step, as shown in Figure 4. However, trying to remove all of the lignin in the pulping step would produce weak pulp because the pulping chemicals are not perfectly selective. They attack carbohydrates as well as lignin, and the extent of carbohydrate attack increases as the content of residual lignin decreases. The residual lignin, although it is only a small fraction of the total amount of lignin present in the original wood, must be removed by bleaching with chemicals that are more selective than the pulping chemicals.

Concerns Related to the Bleaching Process

Although it is similar in nature to pulping, bleaching is different in several important ways. One of these differences is the property of selectivity that I have already referred to. Another is the fate of the effluents from these processes, illustrated by Figure 5. The pulping effluent contains the organic materials removed from the wood during pulping. It is recycled to the kraft recovery system where it is evaporated and burned to generate large amounts of energy and to regenerate the pulping chemicals for recycling to the process. The bleaching effluent on the other hand, because it contains chlorides, cannot be recycled to the recovery system. Instead, it must pass to an effluent treatment system that will satisfy its biochemical oxygen demand and detoxify it before discharging it.

Several different chemicals may be used to bleach kraft pulp. The important ones are listed in Table 2. With one exception, all are oxidizing agents and work by breaking down the lignin structure and making it soluble in alkali. The exception is sodium hydroxide, the alkali used to dissolve the oxidized lignin. It is important to realize that these chemicals are not freely interchangeable. Each has its own set of properties that dictates how and where it is best used in the bleaching process. These properties include a chemical's chlorine equivalent, efficiency, reactivity, selectivity, bleaching ability, and environmental concern quotient.

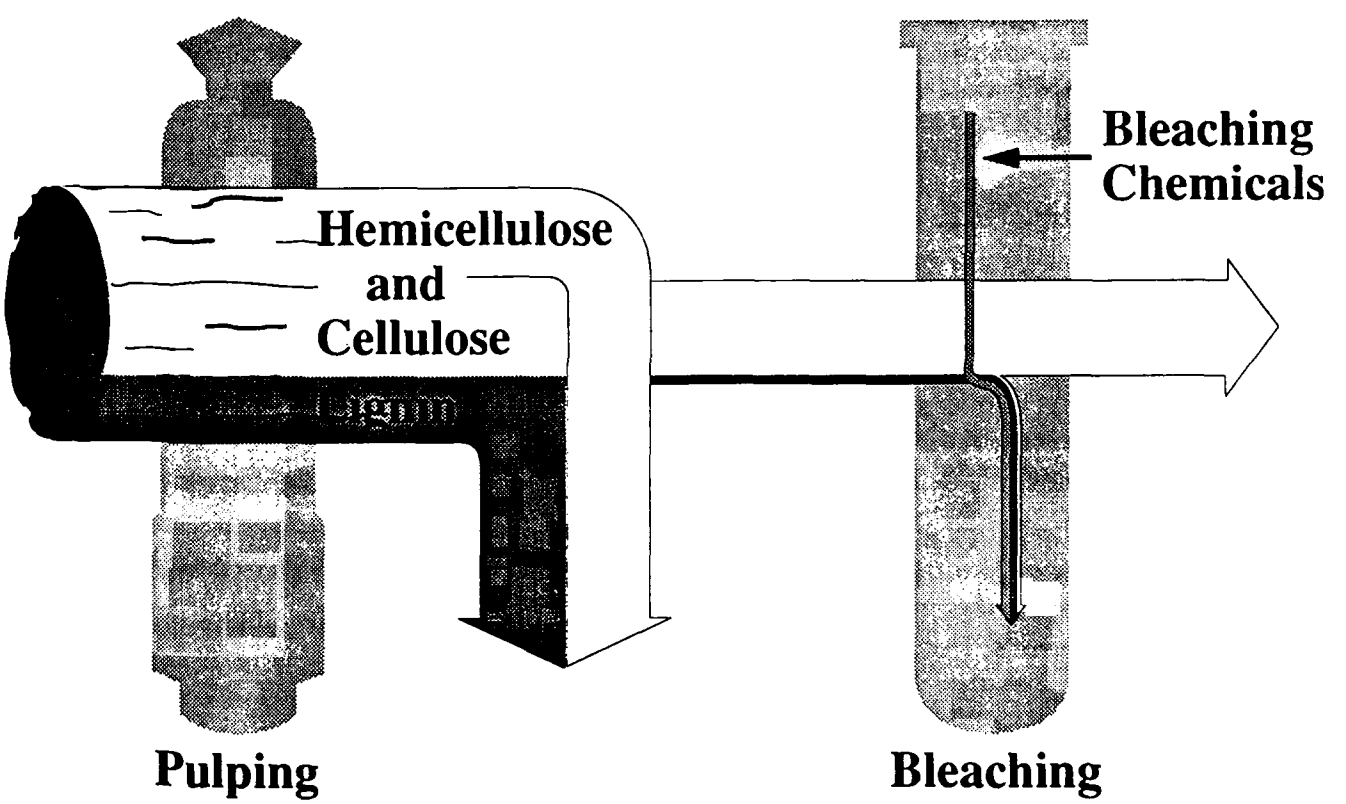

Figure 4.–Sankey diagram showing relative magnitudes of material flows in kraft pulping and bleaching.

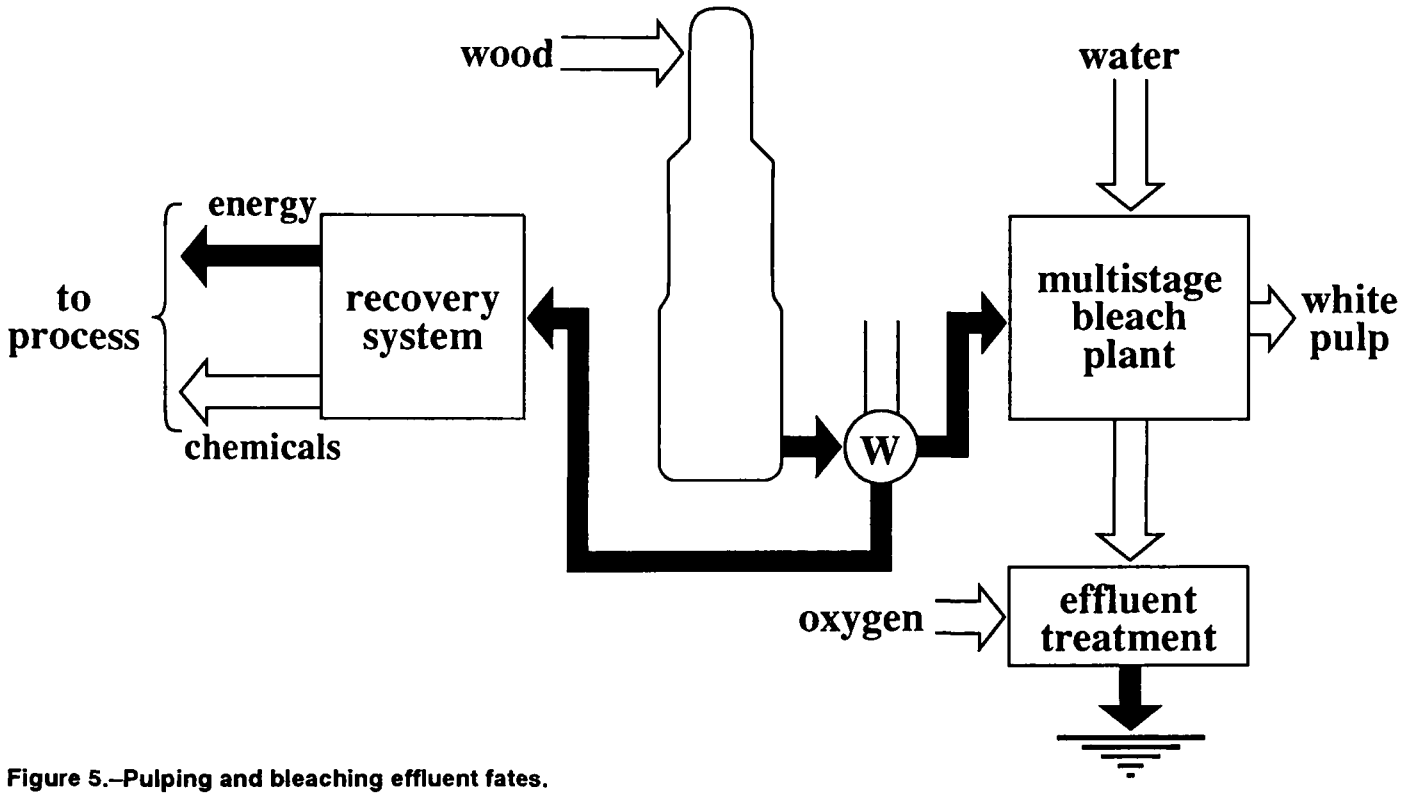

Figure 5.–Pulping and bleaching effluent fates.

Table 2.– Important bleaching chemicals and their formulas and symbols.

NAME	FORMULA	SYMBOL
Chlorine	Cl_2	C
Chlorine Dioxide	ClO_2	D
Oxygen	O_2	O
Hydrogen Peroxide	H_2O_2	P
Sodium Hypochlorite	NaOCl	H
Ozone	O_3	Z
Sodium Hydroxide	NaOH	E

Table 3.– Chlorine equivalent and efficiency ratings of important bleaching chemicals.

CHEMICAL	EQUIVALENT Cl_2	EFFICIENCY*
Cl_2	1.0	H
ClO_2	2.6	H
O_2	4.4	L
H_2O_2	2.1	L
NaOCl	0.9	M
O_3	4.4	M

* Delignifying Efficiency, L = Low, M = Medium, H = High

Comparing Bleaching Agents

Two important properties of bleaching chemicals are chlorine equivalent and efficiency. Table 3 is a qualitative comparison of bleaching chemicals with respect to these properties. The chlorine equivalent is the number of pounds of chlorine that would theoretically be required to accomplish the same amount of oxidation as one pound of the particular chemical. Another way of saying this is that the number of pounds of chlorine that can theoretically be replaced by one pound of this chemical is the chemical's chlorine equivalent.

In general, however, this replacement is not possible in practice because the replacement chemical will perform inadequately in terms of efficiency or some other property included on our list of six. An exception to this statement is that chlorine can usually be completely replaced by chlorine dioxide.

The second property, efficiency, is an indicator of the chemical's ability to oxidize lignin and to realize the potential represented by its equivalent chlorine value. Oxygen, for example, has low efficiency so it is capable of replacing much less than the theoretical 4.4 lbs. of chlorine indicated for oxygen in the equivalent chlorine column of Table 3.

Next on the list of properties are reactivity and selectivity as shown in Table 4. Reactivity is a measure of the chemical's ability to react rapidly and completely with the lignin in the pulp. Reactivity is very high for chlorine and ozone and quite low for oxygen and hydrogen peroxide. For this and other reasons, neither oxygen nor peroxide is capable of completely substituting for chlorine. Selectivity characterizes the chemical's ability to

Table 4.– Reactivity and selectivity ratings of important bleaching chemicals.

CHEMICAL	REACTIVITY	SELECTIVITY*
Cl_2	H	H
ClO_2	M	H
O_2	L	M
H_2O_2	L	H
NaOCl	M	M
O_3	H	L

* L = Low, M = Medium, H = High

remove lignin without damaging cellulose. The selectivity of chlorine and chlorine dioxide are very high; ozone, on the other hand, has low selectivity.

The last two criteria for comparing bleaching chemicals are their particle bleaching abilities and their environmental concern quotient. Table 5 compares bleaching agents with respect to these properties. Particle bleaching ability represents the power of the chemical to disintegrate and decolorize particles that would otherwise show up as dark specks on the paper. The chlorine-containing compounds excel in this ability; ozone has the least.

The final criterion for judging a bleaching chemical is the amount of environmental concern its use engenders among the general public. Such concern may or may not reflect the chemical's actual effects on the environment. Environmental concern is highest for chlorine and lowest for non-chlorine-containing bleaching agents.

The Bleaching Sequence

An important consideration in designing processes to bleach kraft pulp is that none of these chemicals

Table 5.– Particle bleaching ability and environmental concern ratings of important bleaching chemicals.

CHEMICAL	PARTICLE BLEACHING ABILITY*	ENVIRONMENTAL CONCERN
Cl_2	H	H
ClO_2	H	M
O_2	M	L
H_2O_2	L	L
NaOCl	H	H
O_3	L	L

* L = Low, M = Medium, H = High

can be used alone. It is always necessary to use combinations of at least two of them. Another consideration is that it is always more efficient to use two oxidizing treatments separated by an alkaline treatment than to use a single oxidizing treatment. These principals dictate the use of multistage bleaching sequences. An example is the CEDED sequence, illustrated in Figure 6, which consists of sucessive treatments with chlorine, alkali, chlorine dioxide, alkali, and chlorine dioxide. This sequence was standard in the 1970s and early 1980s.

In this and similar sequences, the bulk of the residual lignin is removed in the first two stages. Therefore these stages have the greatest potential for environmental effect. For example, dioxins are formed exclusively in the first stage and most are liberated from the pulp in the second stage. Concern over the generation of chlorinated organics, measured as adsorbable organic halogens (AOX), has initiated a trend toward progressively greater use of chlorine dioxide to replace chlorine in the first stage. It has, in addition, become common to use oxygen in the first alkaline extraction stage, converting it from an E-stage to an EO-stage.

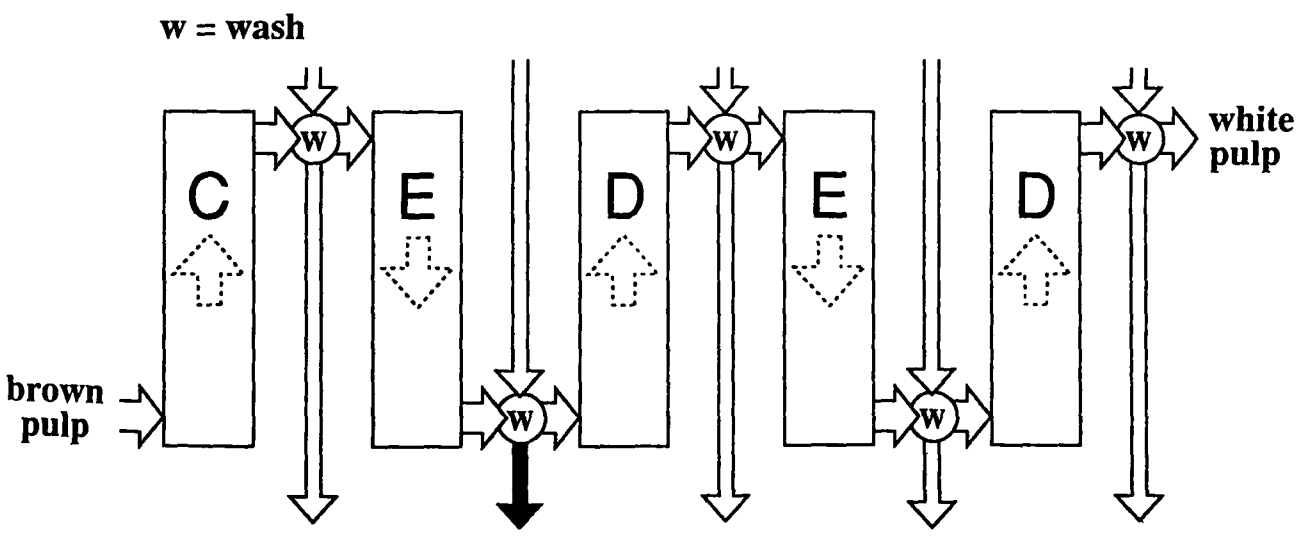

Figure 6.–The CEDED sequence.

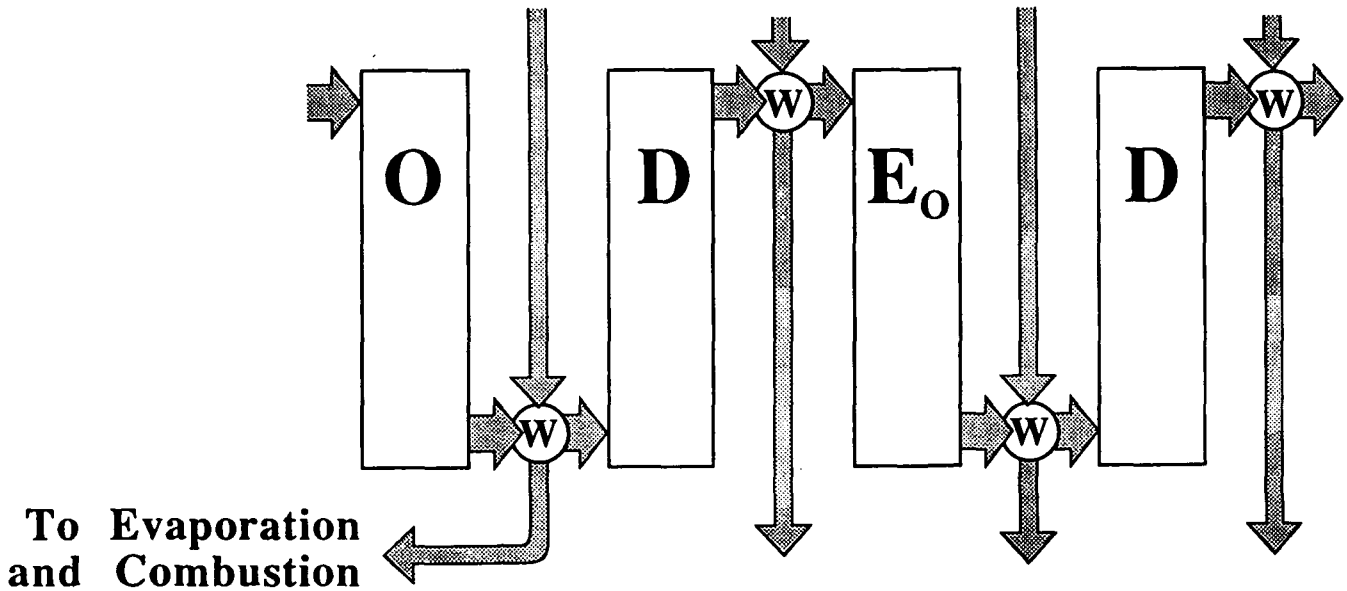

Figure 7.–The ODEOD sequence.

Oxygen is also used as a first bleaching stage to remove part of the residual lignin, usually about 40 percent. This removal decreases the amount of chemicals needed in the subsequent stages. If the next stage is a chlorine or chlorine dioxide stage, it results in a corresponding reduction in the generation of chlorinated organic compounds, total dissolved organics, and color. An attractive feature of such a system is that the effluent from the oxygen stage contains no chlorides and can be easily recycled and burned. An example of a sequence that uses oxygen as the first stage together with complete replacement of chlorine by chlorine dioxide and oxygen reinforcement of the alkaline extraction stage is shown in Figure 7. This OD(EO)D sequence is capable of limiting chlorinated organic material production to extremely low levels.

Concluding Remarks

The preceding discussion may be briefly summarized as follows: pulping, or fiber separation, can be accomplished by a variety of chemical and mechanical processes. Bleached chemical pulps are superior to mechanical pulps in strength, brightness, and permanence. Bleaching is done for a variety of reasons, not just to increase brightness; and bleaching chemicals differ from one another with respect to a variety of criteria including selectivity, efficiency, reactivity, and actual bleaching ability or particle removal. Oxygen bleaching can reduce the amount of AOX in the bleaching effluents as much as 50 percent.

This simple list of facts has a number of implications vis-à-vis pollution prevention: (1) The choice of pulping process can itself be a means of pollution prevention: the currently dominant kraft pulping process, by virtue of the closed-cycle nature of its recovery system is environmentally superior to some of its predecessors; on the other hand, mechanical pulping cannot generally be substituted for kraft pulping for the sole purpose of achieving environmental benefits, because of large differences in the pulps' properties. (2) Bleaching agents cannot be freely substituted for one another to improve effluent properties because of (a) inherent differences in their behaviors and (b) the resulting effects on the pulps' properties. (3) In spite of constraints on the interchangeability of bleaching agents, the quality of bleaching effluents can be improved by means of a growing list of technologies, such as the use of oxygen to furnish part of the necessary oxidizing power, and the substitution of chlorine dioxide for chlorine. Continued evolution of such technologies may be expected, in response to demonstrably real environmental needs.

Chemicals Used in the Pulp and Paper Industry

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Vice President, Human and Environmental Protection
The Mead Corporation
Dayton, Ohio

Pulping and bleaching technologies are not the only source of chemical use in the pulp and paper manufacturing industries. Other chemicals are used, and some of these are sources of exposure to our employees, our neighbors, and the environment. When you think about the various pulping processes, the different wood species that we use, and the many products that we make available worldwide, you know that we are talking about many different chemicals.

The chemical inventory of the Mead Corporation, for example, contains over 2,000 chemicals that can be used at different times in the many processes that convert wood to paper. The industry also puts many coatings on paper products. These coatings are chemicals. We may also put a variety of raw materials into our products, sometimes with unwanted or unintended by-products being generated in the process. The end result equals lots of different chemicals.

Monitoring Chemical Uses

What do we know about these chemicals, or what can we find out? It takes a large number of comprehensive surveys to understand the chemical exposures in our industries. One snapshot taken at one point in time is insufficient to record potential sources of chemical exposure in our line of work. The government has done some surveys and has some records for some companies. In the 1980s, for example, the U.S. Department of Health and Human Services and the U.S. Environmental Protection Agency (EPA) documented employee exposures to chemicals in our industry. And in my company, since the mid-1970s, we have been doing annual, comprehensive industrial hygiene surveys.

To accomplish this task, we go into our plants and monitor different chemicals through the collection of area samples. Another method that we use to monitor chemical exposures, directly involves the workers. That is, we attach small portable samplers to individuals in the plant. This sampler is usually at waist-level, but the intake port for the sample is on the lapel — close to the worker's breathing zone. These samples are collected for two hours, six hours, and eight hours, depending on the chemical being monitored. Such an extensive program identifies many of the exposures that are present in the work place.

My list of these chemicals (see Table 1) does not include the chemicals that are typically used in the pulping and bleaching processes that we have focused on at this meeting or that we are going to focus on in the next couple of days. However, it does contain examples of different chemical exposures that are found in our industry. We can break the industry down into pulping, bleaching, power, and recovery chemical uses, and have categories left over for other basic processes. We can fine tune our lists even further. My point is that this list from Mead is only a portion of a much broader list.

I should also say that when we do this monitoring — and I believe all companies who do it — also share this information with all employees as part of our employee's right-to-know programs. In addition, it is very clear that communities have a right to know what chemicals they may be exposed to. We have programs that address community rights as well.

Table 1.—Chemicals evaluated through comprehensive industrial hygiene monitoring programs in pulp and paper mills 1970–1990.

	PULPING	BLEACHING	POWER & RECOVERY	PAPERMAKING (COATING, FINISHING, CONVERTING)
Ammonia				X
Anthraquinone	X			
Asbestos			X	X
Benzene				X
Calcuim Oxide			X	
Calcuim Carbonate	X			X
Carbon Black			X	X
Carbon Monoxide			X	X
Chlorine		X		
Chlorine Dioxide		X		
Chloroform		X		
Coal Dust			X	
Epichlorohydrin				X
Formaldehyde				X
Hydrogen Sulfide	X		X	
Metals (Flyash)			X	
Metals (Pigments)				X
Metals (Welding)	X	X	X	X
Methanol	X			
Methyl Mercaptan	X		X	
Methylene Chloride				X
Naphtha–VM&P				X
Oil Mist				X
Particulates–				
Respirable	X		X	X
Wood Dust	X			
Total	X		X	X
Petroleum Distillates				X
Sodium Hydroxide	X	X	X	X
Sulfur Dioxide	X	X	X	
Sulfuric Acid	X	X	X	X
Quartz, Respirable Silica			X	X
Welding Fumes	X	X	X	X

Pollution Prevention Technologies

So that's what has happened over the last 15 or 20 years in terms of chemical types and exposures. As a result of knowing more about potential exposures and what effects they may have on humans and the environment, we try to make sure that our efforts meet or exceed the Occupational Safety and Health Administration (OSHA) and EPA requirements or standards.

One way that significant change is made is through pollution prevention, which is source reduction, the effort to discontinue use of these chemicals entirely or substantially through process changes and substitutions. I have here a list of chemicals (see Table 2) that have been essentially eliminated from our company; another company's list might be quite different. Nevertheless, the move to more environmentally desirable chemicals is the type of thing every company is doing to mini-

Table 2.—Chemicals essentially eliminated in Mead as product raw materials or as by-products.

Asbestos
Benzene
Lead Pigments
Mercury and Mercury compounds
PCB's
Penthachlorophenols
Trichlorophenoll

mize the risk to company employees and neighbors from harmful chemical exposures.

I will not go into examples of conventional air and water emissions, their kind of exposures, and what has happened in this area, except to say that we all know that significant reductions have been made over the last 20 years. One comment that I would like to make about some of those end-of-pipe treatments and reductions, however does concerns the solid waste issue. Taking wastes out of the water or air has sometimes meant putting it on the land in landfills.

Here, also, much change has taken place in our industry. If you look at our industry over the last 15 to 20 years, we don't use nearly as many landfills as before. Sludge from our waste treatment plants is not hazardous, and there are large volumes of it. Our disposal methods are clearly undergoing change. Old landfills are being closed with water-tight caps and other kinds of environmental protection, and new landfills are being lined before they are used. Landfills will clearly be used for disposal in the future; it is a method we will always need.

If you look at our industry as it appeared in 1979, 86 percent of wastewater treatment plant sludge went to landfills. Ten years later, this figure has been reduced to 70 percent. So, the trend is moving in the right direction. The recovery of energy from sludge has also grown in the last decade. In the late 1970s, 11 percent of paper industry sludge was burned. In the late 1980s, over 21 percent was being managed for energy recovery. Again, the trend is in the right direction.

This sludge also has physical and chemical properties that can benefit agriculture and mining interests when applied to fields or abandoned strip mines. Land application of sludge has also grown from roughly 2 percent in the late 1970s to over 8 percent in the late 1980s.

The Mead Company, for example, is very much involved in reclaiming abandoned coal strip mines in the state of Ohio. Ohio has over 200,000 acres of abandoned strip mines that are considered very serious or critically in need of reclamation. During the nonwinter months in our operation in Ohio, almost 100 percent of our treated sludge goes to reclaiming these abandoned strip mines. That amounts to more than 200 tons of dry material each day, and as noted previously, there are still many strip mines that need to be reclaimed.

Accomplishments

Let me switch gears a minute to speak briefly about the Superfund Amendments and Reauthorization Act of 1986 (the SARA emissions) and the Toxic Release Inventory (TRI). Over the last several years, our industry and others have significantly reduced these emissions on a voluntary basis. Many pulp and paper companies joined Administrator William Riley's voluntary commitment program — the 33/50 program — that identified 17 different chemicals to be given high priority from EPA's standpoint.

The Mead Corporation participates in this program. Seven of those chemicals were present in emissions at one or more of our 40 manufacturing locations in the United States; however, most of these seven were not in the pulping and bleaching area but in the emissions from other operations. In our case, we use 1987 as the base year, and we have already exceeded the 33 percent reduction target. For six of the seven, we have, in fact, already exceeded the 50 percent reduction target, and the accomplishment has raised our sights. In July of last year, we committed to 75 percent reductions by 1995. We are well on our way to that target.

Another related issue: in April 1992, Administrator Reilly announced that our packaging division, which is headquartered in Atlanta, Georgia, was one of the national winners of the prestigious Administrator's Award for Pollution Prevention. This award was for reducing toxic air emissions by substituting water-based inks for the formerly solvent-based inks used in our printing processes. It took a major effort lasting many years for us to accomplish this substitution. It is truly a pollution prevention technology and resulted in reducing the volatile organic compounds (VOCs) in these emissions by more than 85 percent. We are obviously very proud of our efforts and we are also proud of the recognition from the EPA.

Facing the Future

We recognize that our industry uses a large number of chemicals in a wide range of processes including pulping and bleaching. We also recognize how important it is to protect our employees, our neighbors, and the environment and to operate with an adequate margin of safety. Mead's programs are clearly designed to do that, and we will continue to make sure that we follow those efforts. However, we also recognize that the very stringent technology-based provisions of the 1990 Clean Air Act and the expected wastewater effluent guidelines that are now being revised may require further significant reductions for many of these emissions that we believe could go way beyond what is necessary to protect human health and the environment. These regulatory issues will be discussed in greater detail later in the symposium.

Conventional Pulp Bleaching at Westvaco

Harold L. Hintz
Technical Assistant to the Vice President and Corporate Research Director
Westvaco Corporation
New York, New York

To reduce the formation of chlorinated organics in conventional pulp bleaching processes, Westvaco has developed a novel chlorination stage technology that splits the applied chlorine into three doses. This technology was implemented voluntarily in 1989 to control dioxin formation in Westvaco's bleaching operations. In combination with chlorination stage pH control and some chemical adjustments, the formation of key chlorinated dioxins and furans was reduced more than 96 percent to nondetectable levels in effluents and products. The formation of other chlorinated organics has decreased 25 to 50 percent.

Conventional Pulp Bleaching

The chlorination stage is a key stage in conventional pulp bleaching. The overall performance of pulp bleaching sequences depends on this critical first stage, whether or not the chlorination stage is preceded by an oxygen stage or whether it is a modified stage in which chlorine dioxide is applied before, after, or simultaneously with the chlorine.

The success of the pulp bleaching process in terms of bleached pulp quality parameters — brightness, strength properties, viscosity, and dirt level — combined with the efficiency of chemical use depends on getting the right chemical reactions to occur in the chlorination stage. These reactions alter the residual lignin macromolecule so that the lignin can dissolve in the chlorination stage or be extracted in the subsequent caustic extraction stage.

Some chlorine reactions with lignin result in attachment of chlorine to the lignin. Most of the chlorinated organics generated in pulp bleaching are formed in reactions with chlorine, although small amounts result from reactions with chlorine dioxide. These chlorinated organic compounds are known collectively as adsorbable organic halogens (AOX). Trace amounts of chlorinated dioxins and furans can be formed in the chlorination stage. It is possible, with the modifications we have developed in our labs and implemented at our mills, to reduce the generation of dioxin to nondetectable levels in effluents and bleached pulps and simultaneously to reduce AOX levels in conventional pulp bleaching systems.

Chlorine Dioxide Substitution

Most modern chlorination stages use some chlorine dioxide with the chlorine. The amount is usually expressed as the chlorine dioxide substitution. The percent of substitution is calculated from this equation in which the amounts of both chlorine and chlorine dioxide are given in chemical oxidation equivalents or active chlorine:

$$\%\ \text{substitution} = \frac{ClO_2}{Cl_2 + ClO_2}$$

Many different methods for chlorine dioxide substitution have been developed because chlorine and chlorine dioxide are compatible chemicals and can be used together or in sequences. Certain of these approaches offer technical advantages for achieving the best lignin removal or pulp quality.

The combined amount of chlorine and chlorine dioxide applied to a pulp in a chlorination stage is often expressed as a kappa factor.

$$\text{Kappa Factor} = \frac{\%Cl_2 + ClO_2}{\text{Kappa Number}}$$

This term takes into account the normal need to adjust the chemical charges when the amount of lignin to be removed, that is, the kappa number, changes. In a similar way, the chlorine applied relative to the kappa number is known as the chlorine factor:

$$\text{Chlorine Factor} = \frac{\%Cl_2}{\text{Kappa Number}}$$

Westvaco's Program in Review

After trace amounts of dioxin were identified in paper industry matrices in 1987, Westvaco began a testing program at its three mills producing bleached pulp. We also began a research program to understand the cause of dioxin generation and to develop preventive actions. The U.S. Environmental Protection Agency (EPA) and Paper Industry 104 Mill Study confirmed the general levels found in our earlier screening tests (NCASI, 1989, 1990).

Our working hypothesis was that the formation of a minor reaction product, such as dioxin, could be affected by the concentration of molecular chlorine in the reaction system. When a given amount of chlorine is applied to a pulp, it is possible to vary the chlorine concentration in several ways, and by splitting it into three charges, a different profile of concentration versus time results.

The upper part of the graph in Figure 1 shows a typical chlorine versus time curve for a single charge. The bottom curve shows a profile when three charges were used. The high initial concentrations observed with one charge are avoided by using three additions (Hise, 1989). High chlorine concentrations are also avoided by chlorinating at low pulp consistencies, but lowered consistency has limited practicality. Good chemical mixing will avoid local high chlorine concentrations.

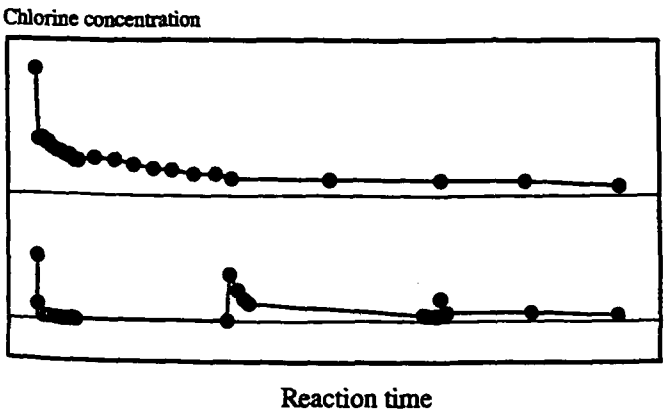

Figure 1.—Consumption of chlorine vs. time (one vs. three chemical additions).

Splitting Chlorine Additions and Adjusting pH

In Westvaco's initial laboratory work, the chlorine charge was divided into two or three additions and compared to a control experiment with a single addition (see Fig. 2). The results show reductions in the 2378-tetrachlorinated isomer of dibenzodioxin (TCDD) of 41 percent for two additions and 53 percent for the three additions. The results for the 2378-tetrachlorinated isomer of dibenzofuran (TCDF) show slightly greater percentage reductions. This work was done on a softwood pulp using a relatively high chlorine factor of 0.21 and a 10 percent substitution of chlorine dioxide. The pulp was not washed between chlorine additions in order to simulate a more practical process for commercial bleaching.

Addition Method	2378-TCDD (ppt)	2378-TCDF (ppt)
One charge	Base Case	
Two charges	-41%	-45%
Three charges	-53%	-70%

Chlorine factor, 0.21
10% ClO_2 substitution

Figure 2.—Effect of splitting chlorine addition on 2378-TCDD/F in C-stage pulp.

Studies in Canada and at North Carolina State University have also shown the potential for varying the reaction products of chlorination by changing the way chlorine is added. They found a clear decrease in the amounts of chlorophenols formed when the chlorine was added continuously as compared to the amounts formed after a single large addition of chlorine (Liebergott, 1984; Marwah et al. 1992).

In addition to splitting the chlorine charge, the concentration of the chlorine molecule in solution can be affected by adjusting the pH. The hydrolysis of chlorine to form hypochlorous acid and hydrochloric acid is an important reaction in pulp chlorination. The chlorine molecule concentration can be controlled by shifting the hydrolysis equilibrium toward hypochlorous acid. Decreasing the total active chlorine concentration forces the equilibrium toward $HOCl + H^+ + Cl^-$. This effect can be achieved by lowering the chlorination stage consistency or by splitting chlorine additions. The chlorine molecule concentration can also be kept low by reducing the concentrations of hydrogen and chloride ions, for example, by avoiding

chlorination filtrate recycle. Controlling the pH level by alkali addition is also effective.

Figure 3 shows how the distribution of chlorine species changes as pH is adjusted. Many commercial chlorinations finish in a low (1 to 2) pH range in which the chlorine molecule is the predominant species of active chlorine. As the pH increases, so does the active chlorine present as hypochlorous acid.

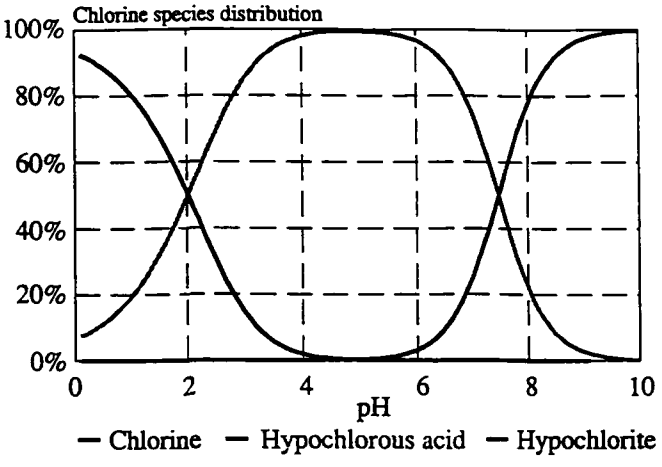

Figure 3.—Chlorine species at varying pH (total active chlorine = 0.1 M).

The effects of pH were tested in laboratory experiments using a single addition of chlorine. The formation of TCDF is clearly reduced when the pH measured at the end of the reaction is increased (see Fig. 4). Similar results have also been reported by researchers at the Pulp and Paper Research Institute of Canada (PAPRICAN) (Berry et al. 1989). Higher amounts of hypochlorous acid and less molecular chlorine at the high pH levels reduce TCDF formation. The nature of the delignification reactions also shifts with pH since hypochlorous acid is known to react with lignin through oxidation reactions. Molecular chlorine will also react through oxidation, but substitution reactions are favored.

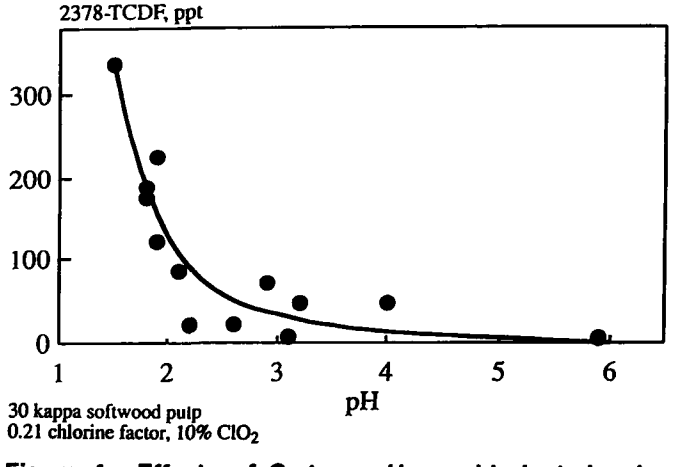

Figure 4.—Effects of C-stage pH on chlorinated pulp TCDF.

A potential result of increased chlorination pH is chemical attack by hypochlorous acid on the pulp carbohydrates and loss of pulp viscosity and strength. Our experiments with a single charge of chemicals showed this possibility. Other experiments and our commercial experience show that this problem can be avoided.

Controlling the Chlorine Factor and Contaminants

The amount of chlorine applied is naturally an important variable controlling dioxin formation. Swedish researchers first showed a link between the amount of dioxin formed and the chlorine used (Kringstad, 1988; Axegård, 1989). Chlorine use was expressed in terms of a chlorine factor.

Axegård's data (see Fig. 5) suggest a rapidly increasing level of dioxin above certain chlorine applications. Dioxin approached nondetectable levels as the chlorine factor decreased to about 0.15. Chlorine factors below 0.20 were obtained in these experiments by increasing the chlorine dioxide substitution for chlorine.

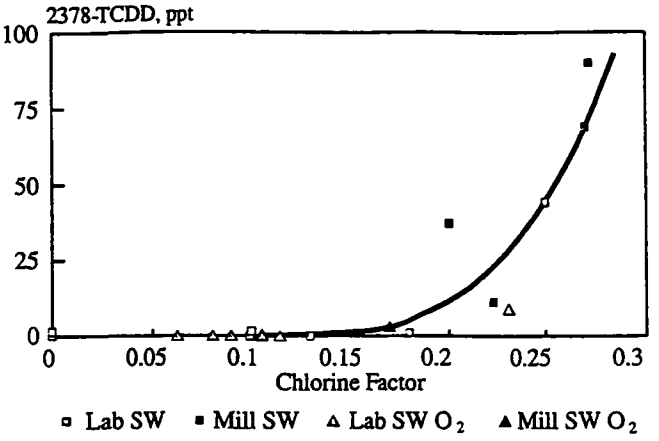

Figure 5.—Bleached pulp TCDD and chlorine factor (Axegård, 1989).

These and other data suggest reducing dioxin formation by reducing the amount of chlorine used. Many process changes have been proposed to reduce chlorine use. In a few mills, the chlorine factor can simply be reduced and adjustments made in the later stages of bleaching to compensate for the reduced delignification in the first stage. Chlorine dioxide substitution can be used to reduce the chlorine factor while maintaining normal levels of first stage delignification.

Chlorine use can also be reduced by processes that leave less lignin in the unbleached pulp. Oxygen bleaching or extended delignification can reduce the requirements for chlorine by 40 percent. These processes require major capital investments to implement. Also, even when bleaching pulps

with lower lignin content, it is still important to control the chlorine factor to avoid dioxin formation.

Contaminants, particularly unchlorinated dibenzodioxin and dibenzofuran, are now well-established contributors to dioxin formation (Allen, 1988; Berry, 1989; Hise, 1990). Laboratory experiments and mill experiences show the importance of washing the unbleached pulps before chlorination. Because the defoamers used in brown stock washing can be a source of dioxin precursors, it is important to use only good quality products at minimum dosages. Good washing will reduce precursor concentrations and allow bleaching with less chlorine. Thus, incremental improvements in brown stock washing and defoamer control were parts of our program (Hise, 1992).

Conclusion

The results from these changes in Westvaco's bleaching operations have been excellent. Dioxin formation has decreased more than 96 percent from the levels measured in 1987. Currently, our dioxin testing program, using the most modern instrumentation available, indicates that our effluents and products are at nondetectable levels for TCDD. All regulatory standards are being met at levels approved by EPA.

Note that these results are from the conventional bleaching technology except for the addition of Westvaco's approach to splitting the chlorine additions and controlling pH.

The significance of other chlorinated organics (AOX) as an environmental measurement has been widely debated. A review of available data indicates no effect when AOX in the effluent is less than 2 kg per metric ton of bleached pulp. A target of 1.5 kg per tonne has often been discussed as a regulatory target.

The process changes implemented to control dioxin formation have resulted in decreases in the AOX levels in the effluents from Westvaco treatment plants. AOX levels generated in the process have been reduced 25 to 50 percent, and with a 30 to 50 percent decrease in the biological treatment process, the levels in our effluents are well below 1.5 kg per ton.

The technology discussed in this paper has been in use at Westvaco mills for over three years — all of the company's bleaching lines are now using it. The equipment for split chlorine additions was purchased and installed in a year or less, and capital requirements were moderate compared to other alternatives. Adjustments in the chemical applications and operating strategies were rapidly implemented and control of the process has been excellent.

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Panel 2:
Overview of Technologies of Paper Manufacturing

Question and Answer Session

■ **Valerie Harris,** *Midwest Research Institute:* My question is for Tom McDonough and Harold Hintz. We talked about two very different approaches to reducing dioxins and furans in the effluent. Earlier this morning, we also talked about a multimedia approach to pollution prevention. So my question is, what are the multimedia impacts, for example, in oxygen delignification? There will be an increase of solids to the recovery cycle. Are there disadvantages or advantages to that? What are its various cost impacts? And the same questions are associated with pH control and stage chlorine control for the conventional chlorine bleaching.

■ **Tom McDonough,** *The Institute of Paper Science and Technology:* I can address the specific part of your question. There are certainly many costs and disincentives associated with installing oxygen delignification in the system — you mentioned one or two of them. An increase of solids in the recovery cycle means that an already overloaded recovery system may become even more overloaded. If so, there's a high capital cost as well. In general it's not an investment that can be justified on the basis of chemical cost savings alone. The environmental benefits play a big role in the justification of the decision to install oxygen delignification.

Worldwide Sales Opportunities for Environmentally Responsible Products

David Mager
Director, Environmental Standards
Green Seal
Washington, D.C.

According to the American Paper Institute, 13 million tons of paper products were exported from the United States in 1991. Yet with only 750 million pulp and paper products customers in a world population of 6 billion, that leaves 5.25 billion people who are not customers. Today the opportunities for the sale of environmentally responsible products is tremendous. In searching for a win/win situation, Green Seal can help manufacturers not only take advantage of those unreached markets but work with them to enourage mutually beneficial solutions to common energy and environmental problems and move toward a healthy environment.

A healthy environment creates monetary wealth via an annuity income from our global capital assets. These assets are then available for the world's population to enjoy through sustainable development and growth. When we plunder the environment, when we spend our rich global capital assets, we damage the planet's ability to provide for its inhabitants. To make a better environment requires that corporate planners, government regulators, and environmental designers have the right tools to help them select the best targets for their actions.

Green Seal's History

Green Seal was formed to respond to consumers' needs to identify environmentally superior products. Four out of five people say they want to buy Green products, 49 percent say they would even pay more for environmentally superior products. In 1991, 13 percent of all new product introductions were Green. J. Ottman's new book, *Green Marketing: Challenges and Opportunities for the New Marketing Age* (1992), contains survey results indicating that 23 percent of all consumers are putting their money where their mouth is and actually making environmentally responsible purchases. A whopping 61 percent of Americans go out of their way to buy products labeled as environmentally sound and 35 percent boycott companies that are careless toward the environment.

Consumers want to buy Green products, but they are often confused by what a Green product is. Most consumers disbelieve environmental claims that manufacturers make about their own products. Similarly they are distrustful of government labels attesting some products as environmentally superior; such labels could represent the lowest common denominator or be the product of a special interest group that succeeded in getting the government's ear.

In a 1991 Gallup poll, 34 percent said they would be influenced to buy products endorsed by an independent "Green Seal," with Denis Hayes heading the Green Seal organization. Hayes served as International Chair of Earth Day 1990 and writes a weekly column on environmental concerns for *USA Weekend,* which reaches 35 million readers.

Green Seal is a nonprofit organization that sets standards for environmentally superior products and tests products for compliance with standards. Green Seal receives support from foundations and individuals but does not accept contributions from corporations. Green Seal is a member of the American Society for Testing and Materials (ASTM)

and the American National Standards Institute (ANSI). We use both groups' open, public process in setting our standards (see Table 1).

Table 1.—Green Seal inputs to standards.

- Basic research
- Manufacturers
- Trade associations
- Public interest and environmental groups
- International environmental standards organizations
- Federal, State, and regulatory agencies
- Standards organizations
- Independent experts
- Consumers and users

Green Seal works closely with other international standard-setting organizations, particularly with the Environmental Choice Program in Canada to ensure that standards do not become barriers for international trade and that manufacturers don't have to make 65 different products to accommodate 65 different standard-setting organizations.

Green Seal also has a strategic alliance with Underwriters Laboratories (UL), Inc., which serves as Green Seal's primary testing and compliance monitoring laboratory. UL has a field staff of more than 500 people in 73 countries.

Green Seal's board of directors is comprised of leaders of industry, government, and the environmental community. Green Seal has become a bridge between these three groups.

Benefits of Green Seal Certification

The benefits of Green Seal certification, according to the manufacturers who have responded to Green Seal so far, include the following:

- **Increased Sales and Market Share.** Over 80 percent of consumers want environmentally superior products, yet they distrust manufacturers' claims and are dubious about a governmental labeling program. However, these same consumers respond positively to an independent Green Seal Certification Mark on a product. Green Seal has received several substantial grants to promote the Green Seal Certification Mark and certified products through use of TV, radio, and printed public service announcements and toll-free telephone response lines. In addition, the Green Seal has received positive media attention.

- **Reduced Costs of Goods.** Environmental regulations are forcing manufacturers to redesign products and manufacturing processes to make them more environmentally responsible. Designing products to comply with standards for environmentally superior products can reduce costs through the "Rule of Tens": if it costs $10 to create a design criteria, it costs $100 to change the design, $1,000 to change the prototype, $10,000 to make a change in preproduction, $100,000 to make a change in production, and $1 million to recall a product from the field.

  Many paper companies, instead of becoming "victims" of regulation, have installed environmentally responsible manufacturing equipment, processes, and practices. I have visited plants in which sludge, which used to be carted off to landfills, is now sold as a landfill sealer — creating income from a former expense. Some plants have installed new water treatment facilities, thereby saving huge amounts of money. Other plants allow waste haulers to bring in paper wastes, which are subsequently recycled and sold as paper products. During this conference, we have learned about techniques that use chlorine for bleaching in small doses at intervals, instead of one large dose. This practice significantly reduces the amount of chlorine required and saves money.

- **Prevent Government Product/Process Regulations.** When products and processes are designed and built for environmental excellence and when industry acts in a proactive, environmentally responsible manner, government regulation is no longer needed. Regulatory compliance adds significantly to costs.

  New Federal regulations state that in the presence of an existing voluntary standard, regulations need not follow. The voluntary standard can be the basis for government procurement decisions. And as Raymond Coates, winner of the 1991 Nobel Prize in economics, points out, when companies fulfill their "social contract" with consumers, no one needs regulations. Government regulations are created when industry fails to maintain this contract.

- **Regulatory Compliance.** On July 28, 1992, the Federal Trade Commission (FTC) issued new *Guides for the Use of Environmental Marketing Claims* in response to a proliferation of meaningless and misleading environmental advertising and product claims. The

Guides say environmental claims need to be substantiated by "competent and reliable scientific evidence" and "conducted in an objective manner by persons qualified to do so, using procedures generally accepted in the profession." Green Seal Certification provides such substantiation.

- **Increased Corporate Stock Values.** Companies with poor environmental performance records (as indicated by the Toxic Release Inventory reports) have low earnings ratios and poor stock values, regardless of their profitability. Stock analysts carefully review public companies' environmental records as part of the basis for making stock-buying recommendations.
- **Improved Employee Morale.** Employees love to be on the side of the "good guys." Worker productivity is high in companies that are proactive environmentally. Conversely, employee morale suffers when workers feel guilty about their involvement in in environmentally damaging company actions and policies. In the extreme, unhappy employees can become whistleblowers causing a very expensive and damaging experience for companies.
- **Recognition For Environmental Achievement.** Corporations seek compliance with published environmental standards to gain recognition for their service to the planet. The Green Seal announces their accomplishment to workers, customers, suppliers, the local community, and the world at large.
- **Better Community Relations.** Environmentally responsible manufacturing reassures residents who live near a plant. It addresses their concerns about the community right-to-know laws, and it fosters more cooperative company/community relations.
- **Improved Relations with Peers, Friends, and Family.** Environmentally responsible products, processes, and services turn workers, product designers, and decisionmakers into heroes in the eyes of their colleagues, friends, and family. Decisionmakers at companies with bad environmental performance are shunned and ostracized in social circles and by their families.

  The tuna boycott in the late 1980s, protesting the killing of dolphins during tuna fishing, was successful not because it did economic damage to tuna producers, but because a granddaughter wouldn't sit on the lap of the company chairman because his company was killing dolphins. A revealing article in *The New York Times* disclosed that chromium platers were cleaning up their operations not because regulatory compliance made business unprofitable, but because their neighbors wouldn't talk to them anymore.

Voluntary Environmental Standards Versus Life Cycle Analysis

Green Seal is one of only 50 invited worldwide participants in the Society for Environmental Toxicologists and Chemists (SETAC) workshop and the U.S. Environmental Protection Agency (EPA) peer review group on life cycle analysis. Although we now have an accepted methodology for measuring the environmental effects of a product throughout its life cycle, it is not yet possible to discover the sum of these impacts. That is, no useful number is produced when we add the total tonnage of pulp used, the kilowatt hours that go into transforming pulp into paper, the weight of the chlorine used for bleaching, the weight of chlorinated organic effluents, the carbon dioxide, monoxide, nitrogen oxides, and sulfur compounds that are emitted, the millions of gallons of water discharged at elevated temperatures, and the tons of packaging and paper discarded after use.

This is why SETAC, the EPA, and the States' attorneys general all agree that life cycle analysis should not be used as the basis for product labeling or public policy. Nevertheless, life cycle analysis technologies and methodologies are pushing the envelope in environmental matters — just like the Apollo space program stimulated developments in electronics and computers. New and improved ways of making environmental evaluations of products can result from life cycle analysis, which already influences the way Green Seal sets its environmental standards.

Green Seal's voluntary standards are set at the level of environmentally superior products, in contrast to mandatory government regulations that are generally set at minimum performance levels (see Fig. 1). Standards are set at Green Seal using a life cycle approach. We look at all aspects of a product's impact on the environment, from preproduction to manufacturing, packaging, distribution, use, and ultimate disposal. The energy and materials that are used, the emissions to air and water, solid waste considerations, and toxicological and ecological implications are considered. Green Seal standards address a product's environmental performance, its packaging, its general per-

formance, and its labeling requirements. For general performance criteria, Green Seal's standards defer to ASTM, ANSI, the Technological Association of the Pulp and Paper Industry (TAPPI), or other industry-accepted performance criteria.

After doing basic research for each standard, we solicit input from every group that has an interest in the product — manufacturers, trade associations, public-interest and environmental groups, UL, Federal, State and regional regulatory agencies, other standards organizations, and consumers. Green Seal builds a consensus on the issues and then sets a proposed standard at a level reflecting environmentally superior products.

The proposed standard then undergoes a "purification by fire": a public review process. The proposed standard and its rationale, along with documented and technical references, is distributed to all manufacturers of the product and any person or organization who requests it. Comments received are researched and all get responses.

Green Seal standards have been set for facial tissue, toilet tissue, printing and writing paper, re-refined engine oil, showers, sinks, toilets, and energy-efficient lighting. Proposed standards have been released for household cleaners, paper towels, and paper napkins (see Fig. 2). Proposed standards are being finalized for newsprint and newspapers, paint, thermal windows, major household appliances, insulation, and reusable shopping bags. We are also working on an amendment to our printing and writing paper standard to include coated paper.

As an example, Green Seal's standard for toilet tissue addresses recovered paper and post-consumer material, ASTM performance specifications, no inks or dyes, certain chemicals that cannot be used in deinking, restrictions on the adsorbable halogen content (AOX), restrictions of toxics and packaging (including minimum size requirements), and a requirement that all products must comply with existing environmental law.

After a standard is set, the Green Seal process provides for a manufacturer to apply to Green Seal to have the product tested against the standard. If a test product meets the requirements, it is awarded certification with the provision that the manufacturer agrees to ongoing compliance monitoring, including unannounced site visits and product testing.

Green Seal has a proposed standard for paper towels and paper napkins. I invite you to review this and other Green Seal proposed standards and provide your comments. Your participation in this process will ensure that the standards reflect your knowledge and experience and point the way toward a new paradigm of solving our world's environmental problems.

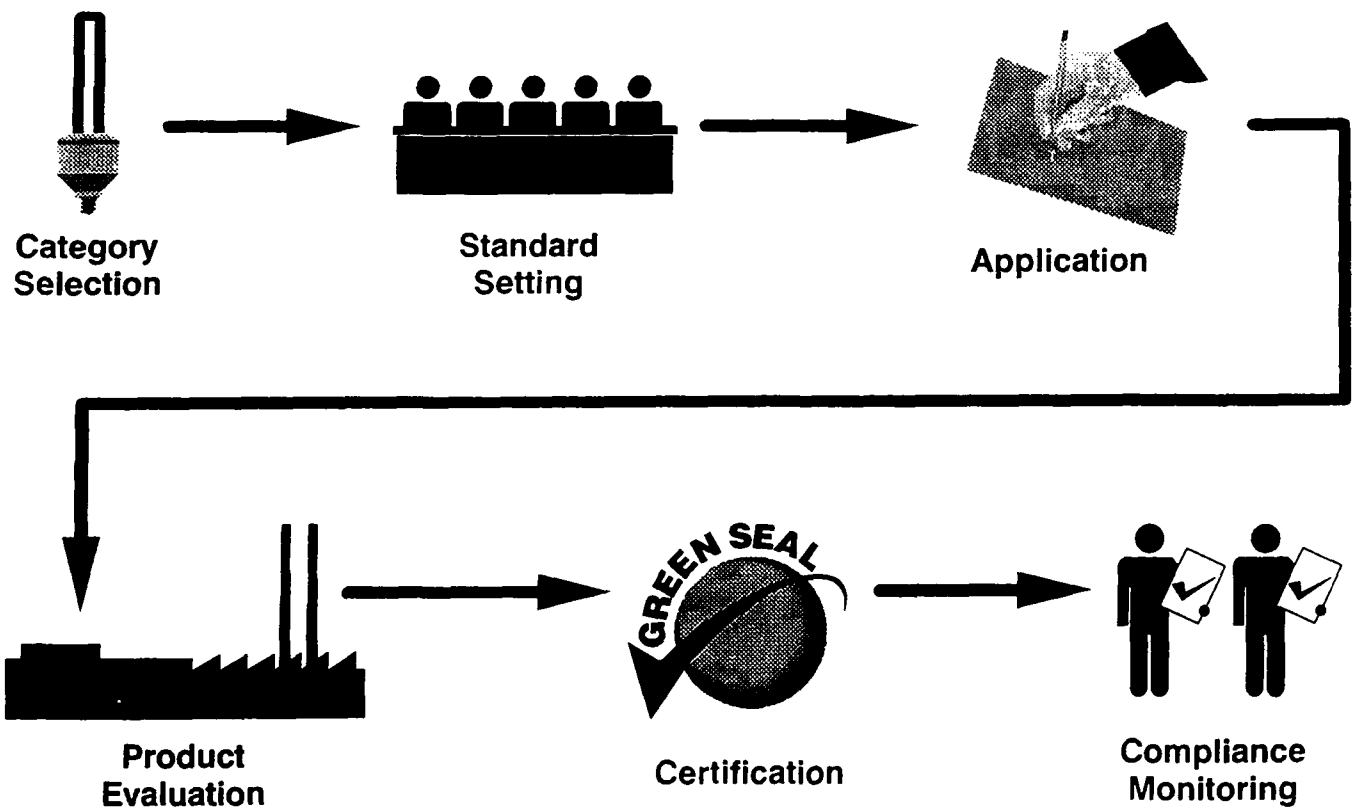

Figure 1.—The Green Seal process.

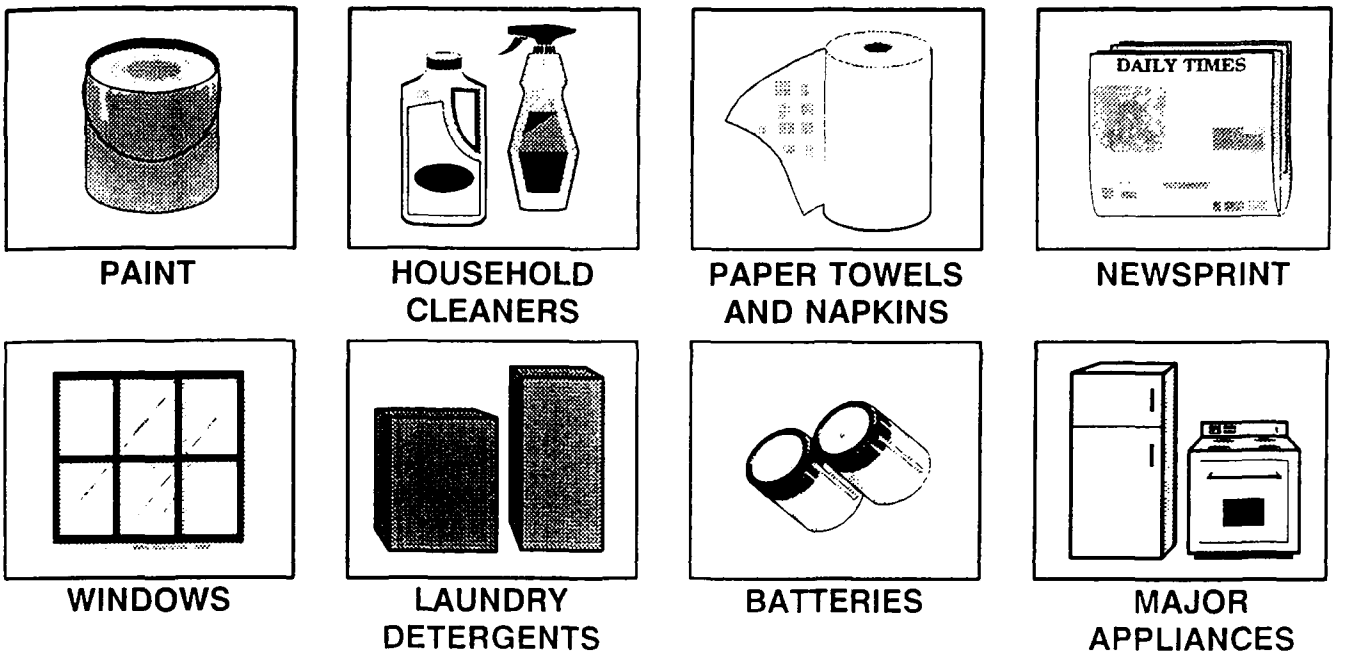

Figure 2.—Standards under development.

Low Kappa Continuous Pulping

C. Bertil Stromberg
Director, Research and Development Laboratory
Kamyr, Inc.
Glens Falls, New York

Much research has been performed in the pulp and paper industry over the last few years to minimize the environmental impact of chlorine and chlorine dioxide bleaching by reducing the need for these chemicals. The solution has been to reduce the lignin content in the pulp going into the chlorine and chlorine dioxide bleaching stages. A combination of cooking, oxygen delignification, and nonchlorine compound (hydrogen peroxide and ozone) bleaching have been used in this process.

One drawback to oxygen and peroxide is their limited ability to remove and brighten lignin. Ozone is effective in removing lignin, but as it also attacks cellulose, its use is limited to about 1 percent on pulp (Liebergott et al. 1992). One way to improve the lignin removal efficiency is to chelate for metals removal before the peroxide, oxygen, and ozone stages, thereby reducing the breakdown of the reagents and the cellulose and achieving a brighter, stronger pulp at the same chemical charge. There are still limits to what these chemicals can do, as shown by work done at the Pulp and Paper Industry of Canada (PAPRICAN) (see Fig. 1). When laboratory kraft pulps at different kappa numbers were subjected to peroxide bleaching after a chelating stage, the dependence of final brightness on the incoming kappa number is clear (Anderson, 1992).

Another way to reduce the bleach chemical demand is xylanase enzyme treatment of the pulp prior to bleaching, which makes the pulp appear as if the kappa number is 10 to 30 percent lower, by increasing the accessibility of the lignin in the fiber structure (Farrell, 1992; Munk, 1992; Senior et al. 1992; Senior and Hamilton, 1992).

To lower the kappa number below that achieved today by conventional oxygen delignification, the kappa number in the cooked pulp has to be decreased substantially. In the last 10 to 15 years, many improvements have been made in the ability to lower the kappa number from both batch and continuous cooking systems. This paper examines the status of low kappa pulping in modified and extended modified continuous cooking techniques.

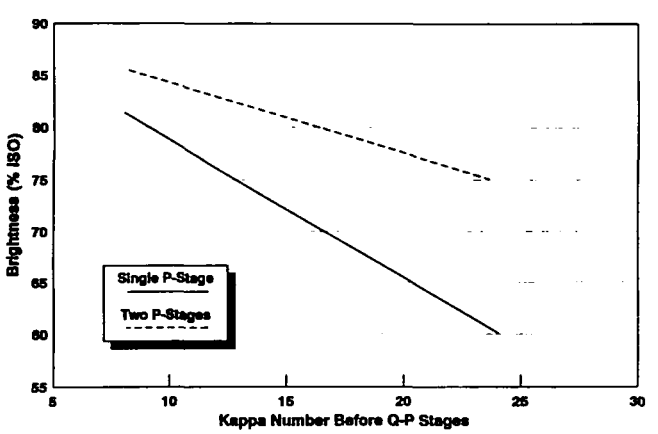

Figure 1.—Peroxide stage brightness versus incoming kappa kraft pulps. Source: Pulp and Paper Research Institute of Canada (in press).

Principles of Modified Continuous Cooking

The basis for kraft extended delignification was developed at the Swedish Pulp and Paper Research Institute (STFI) and the Royal Institute of Technology in Sweden (Johansson et al. 1984). Research indicates that the selectivity of the kraft cook could be increased by the following process parameters:

- the alkali concentration should be low and even throughout the entire cook;
- the concentration of sulfide ion should be high, particularly at the beginning of the cook; and
- the concentration of dissolved lignin should be low, particularly at the end of the cook.

In addition, it is known that the selectivity of the kraft cook is also improved when the cooking temperature is kept as low as possible.

These principles were applied to a Kamyr digester, by adding a circulation loop below the normal extraction screens, and diverting about 20 percent of the total white liquor charge to this circulation, which is heated to full cooking temperature. The latter part of the cook is thus carried out by bringing the cooking liquor countercurrently to the chips. Full-scale 1983 trials in Finland confirmed the lab findings (Kortelainen and Backlund, 1985). All new digesters for bleachable pulp sold since 1985 have been either prepared for, or fully equipped for, MCC® operation. Figure 2 shows a flowsheet for a two-vessel hydraulic digester equipped with MCC®.

Both lab and mill MCC® pulps permit about a 10 percent reduction in bleaching chemicals as compared to a conventionally cooked pulp of the same kappa number bleached to the same brightness. This reduction is mostly the result of the alkali concentration at the end of the cook being higher in the MCC® procedure than in conventional cooking (Kortelainen and Backlund, 1985; Whitley et al. 1990).

The brightness levels that can be achieved with a given bleach sequence are also consistently higher for MCC® pulps. Figure 3 shows lab data for bleach chemical consumption versus brightness for Canadian hardwood chips cooked in the lab to the same kappa number using MCC® and conventional procedures. Figure 4 shows operating data from a U.S. softwood line, before and after conversion to MCC® (Whitley et al. 1990).

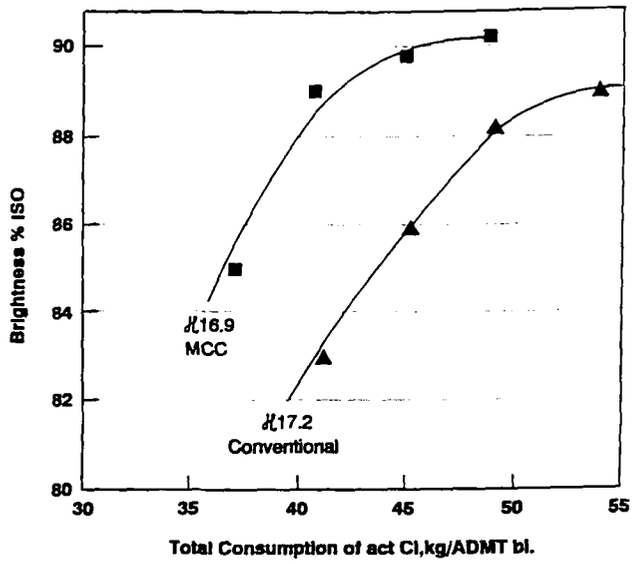

Figure 3.—Bleaching response of conventional and MCC® pulps.

Work by Kamyr, Inc., shows that extending the time in the countercurrent part of the cook further enhances selectivity; the kappa number can now be reduced by 30 to 35 percent over the conventional cooking procedure, with the same bleaching response as for MCC® pulps. These findings led to the introduction of a white liquor addition point to the wash circulation and the ability to bring this circulation up to full cooking temperature, which increases the countercurrent cooking time by two to four hours, as compared to the normal one hour. This process, called the Extended Modified Continuous Cook (EMCC®), has been adopted by many mills, some of which were already equipped with

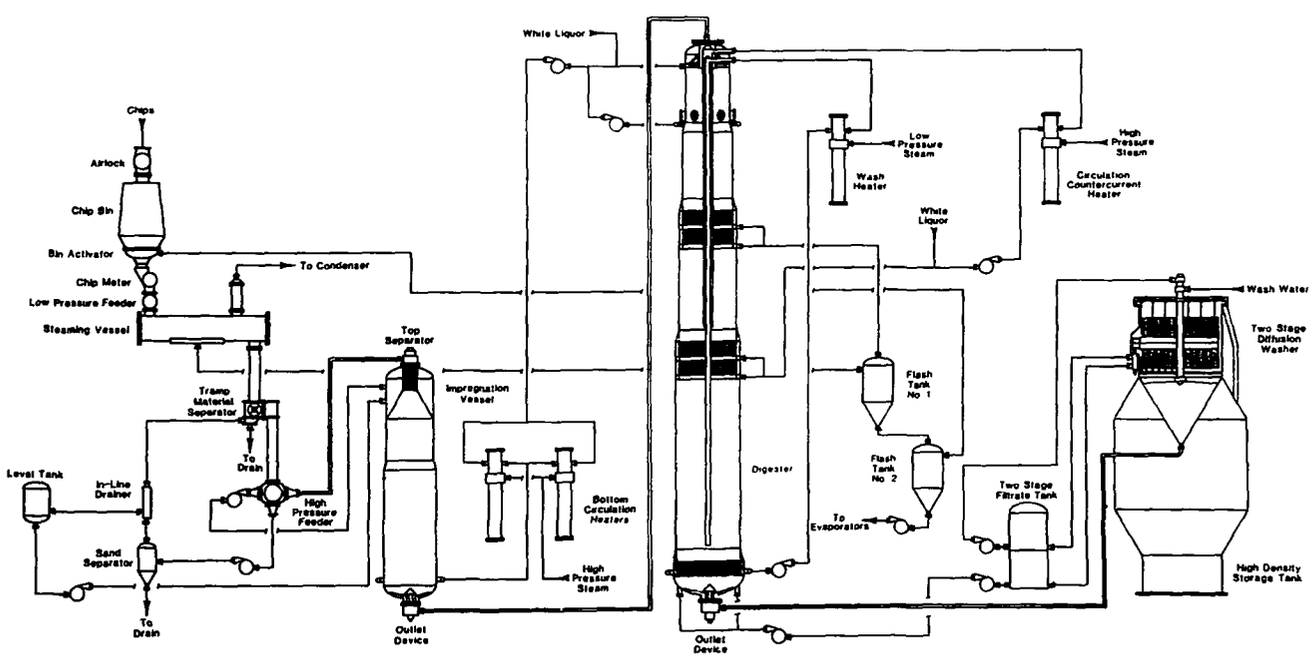

Figure 2.—Two-vessel hydraulic digester with MCC® and two-stage diffuser.

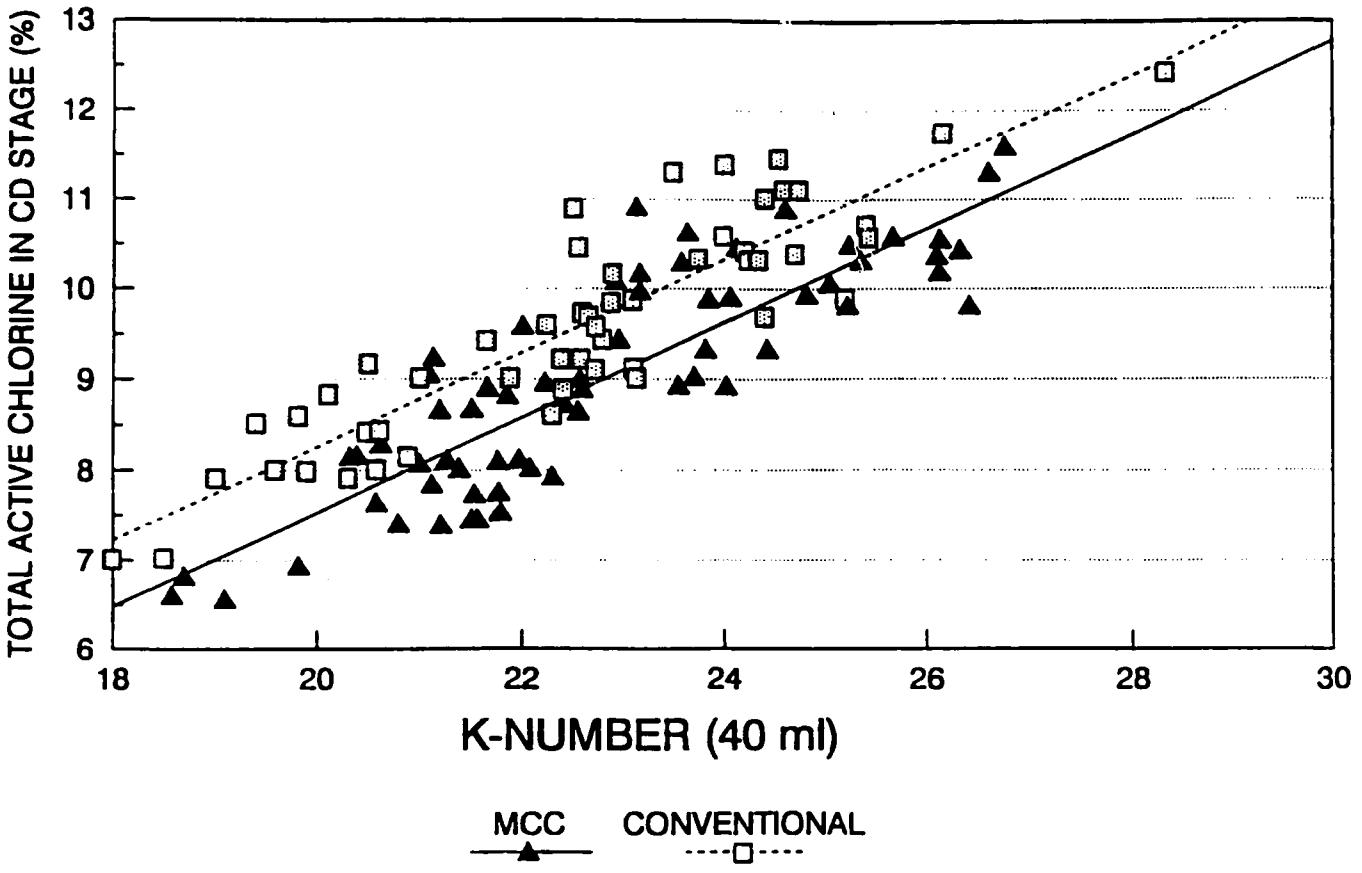

Figure 4.—Cl_2 consumption versus K-NO. (Conventional and MCC® operation.)

MCC® and others that were not originally equipped for countercurrent cooking.

Figure 5 shows the impact on unbleached pulp viscosity of going from a conventional lab cook to an MCC® and an EMCC® cook. A kappa reduction of about 4 units is possible with an EMCC® cook at the same viscosity, as compared to an MCC® cook. The successful application of EMCC® has been confirmed in several mills (Jiang et al. 1992a; Munro, 1991).

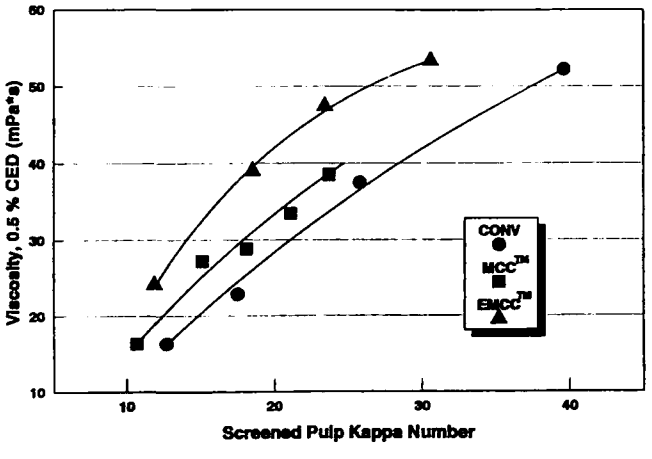

Figure 5.—Pulp viscosity versus kappa number. (Conventional, MCC®, and EMCC® pulps.)

Figure 6 shows a two-vessel hydraulic digester equipped with EMCC®. The addition of white liquor to the wash circulation can also be incorporated on digesters that do not have the MCC® circulation between the wash circulation and the extraction screens.

Currently, about 30 mills in the United States and Canada and about 10 mills in the rest of the world practice some form of MCC® or EMCC®. These numbers correspond to about 25 percent of the total production of bleached chemical pulp in the United States and Canada and about 10 percent in the rest of the world. As new systems are sold, and older ones are converted, these numbers increase very rapidly.

For these mills, kappa targets are generally 20 to 25 on softwood and 12 to 15 on hardwood. Individual conditions and product requirements in some mills cause them to operate above or below these ranges periodically or all the time, and equipment configurations or capacity limitations sometimes make it difficult or impossible to convert to MCC® or EMCC® using existing digester vessels.

EMCC® is also practiced in continuous sulfite digesters in North America, but there the process is used mainly for operational advantage as it does not improve the kappa number–pulp viscosity relationship (Stromberg, 1991).

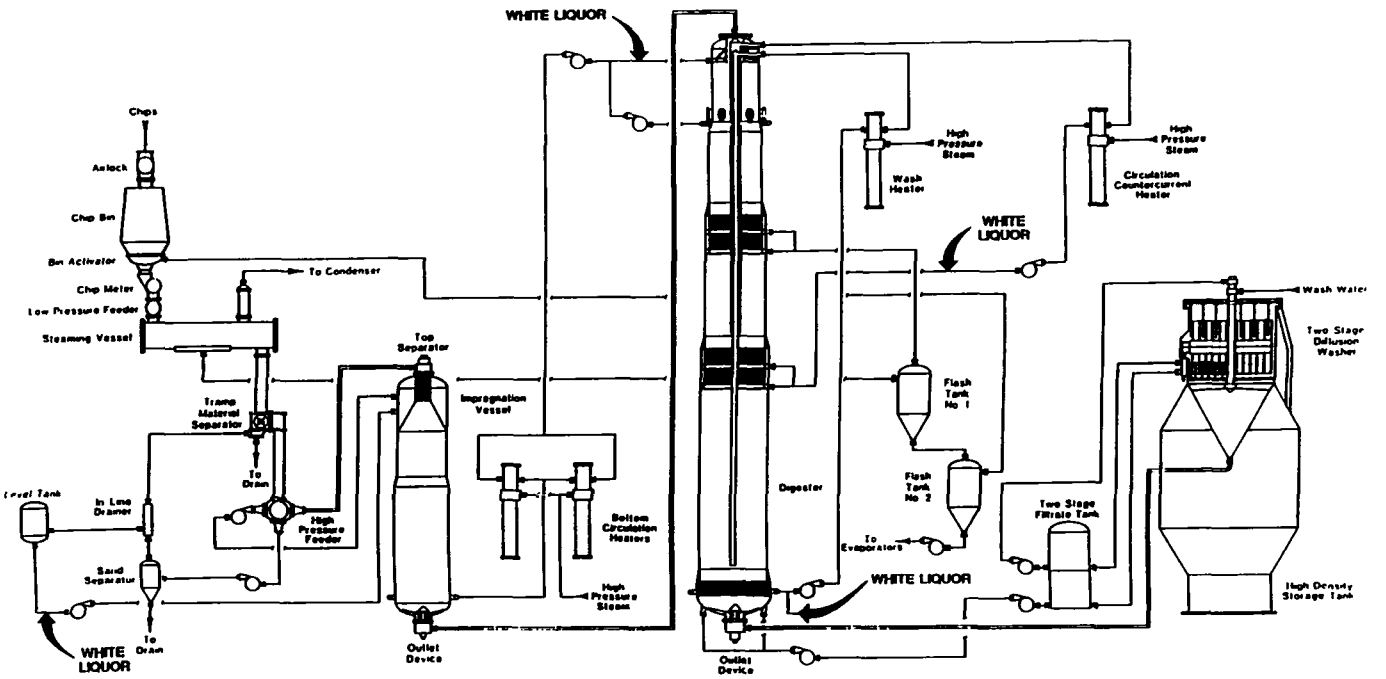

Figure 6.—Two-vessel hydraulic digester with EMCC® and two-stage diffuser.

Low Kappa Continuous Cooking Challenges

With the proven capability of bringing the softwood kappa number down to the low 20s and the hardwood kappa number to the low teens, the next step in the process of reducing the chlorine in bleached pulp is to find the low practical limit. This step has focused on softwood because the environmental impact is more intense for higher kappa pulp and because there are concerns about softwood's ability to retain its strength properties. Pulp yield and chemical and energy requirements are also of interest to determine capacity limitations and operating cost.

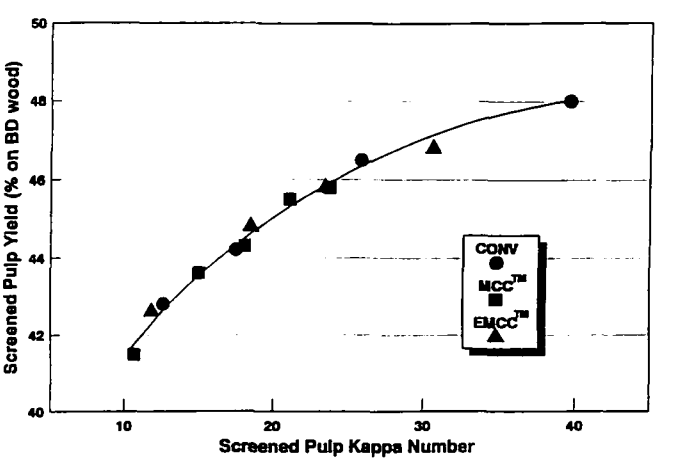

Figure 7.—Laboratory pulp yield versus kappa number. (Conventional, MCC®, and EMCC® pulps.)

Yield

By removing more lignin from the fibers before bleaching, more chemicals are consumed in the cooking or oxygen delignification processes, and more cellulose and hemicellulose are dissolved from the fibers.

The yield loss for the cooking accelerates below kappa 18 for softwood, as shown in lab data (Fig. 7), and for Southern pine as indicated in mill data (Jiang et al. 1992b; Elliott and Walley, 1991). Figure 8 shows the impact on yield by oxygen delignification and final bleaching of four different EMCC® lab produced pulps from Southern pine (Jiang et al. 1992b). The yield loss in oxygen delignification accelerates when the degree of delignification exceeds 50 percent. The final bleached yield is essentially unchanged for a digester kappa

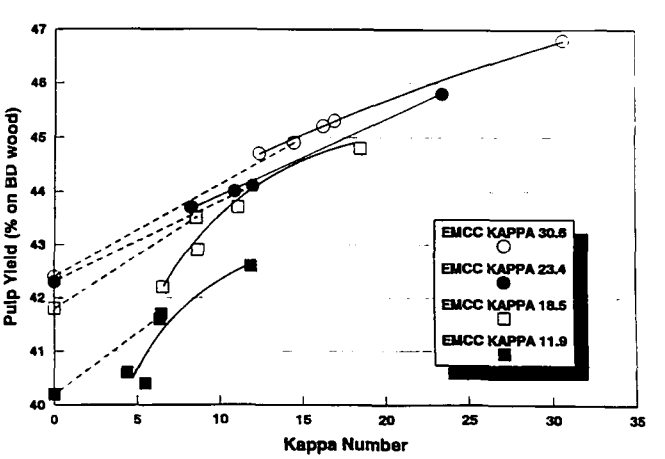

Figure 8.—Laboratory pulp yield versus kappa number. (Combinations of EMCC® and oxygen delignification.)

above 18, as long as the oxygen delignification is limited to a 50 percent kappa reduction. If we compare the pulps cooked to kappa 12 versus kappa 18, the yield loss after bleaching corresponds to an increase in wood consumption of about 5 percent.

Mill MCC® and EMCC® pulps have higher total yield than lab pulps produced from the same chips because the measured hemicellulose content is higher in the mill pulps (Jiang et al. 1992b; Teder and Sandstrom, 1985; Teder and Janson, 1986). Mill MCC® and EMCC® pulps generally also have much lower amounts of rejects compared to conventional pulps produced in the same digester (Whitley et al. 1990). The effect of this reduction on total pulp yield varies between different mills, depending on how the rejects are treated. The yield impacts of hemicellulose and rejects are the same at kappa 12 and 18, so the difference in yield between the two kappa levels is about 2 percent on wood.

Our laboratory data show that a softwood kappa level of 10 after oxygen delignification can be produced without an appreciable total yield loss, although the load on the recovery system will increase considerably, compared to operation at higher kappa levels (Jiang et al. 1992b). The impact of pulp yield will also vary considerably between different mills because of the operating limits of various equipment.

Processes that produce a higher pulp yield are clearly preferred. Lab studies conducted by Kamyr, Inc., show that polysulfide additions also increase the pulp yield for EMCC® pulps (Jiang, 1992). The yield improvement is up to 3 percent on wood at 3 percent polysulfide addition. Figure 9 shows the yield data for the cooked pulps, of which two have been conventionally bleached using a D-Eop-D-nD sequence. The yield improvement from the polysulfide addition is maintained after bleaching. The data also show that the relative yield difference between kappa 12 and kappa 18 discussed previously does not change with the polysulfide addition. Interestingly, the low kappa EMCC® pulps did not show the typical decrease in tear-tensile strength that normally accompanies polysulfide treatment for conventional pulps at higher kappa numbers (Fig. 10).

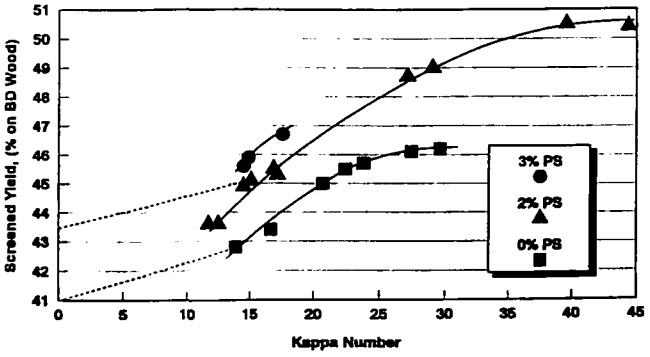

Figure 9.—Effect of polysulfide addition on pulp yield. (Conventional and EMCC® pulps.)

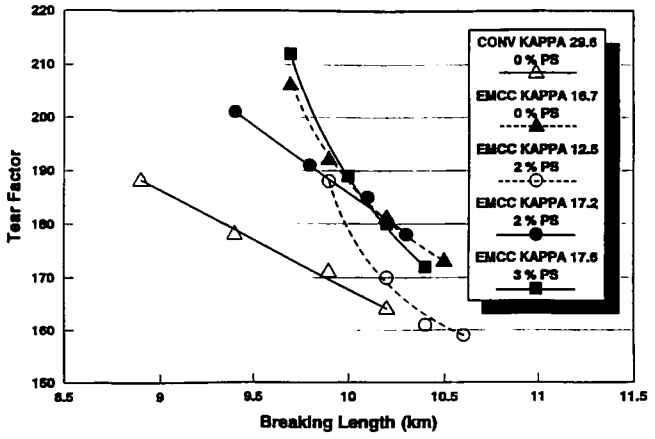

Figure 10.—Effect of polysulfide on EMCC® pulp strength. (Tear factor versus breaking length.)

One obstacle associated with polysulfide pulping is the very high sulfur to sodium ratio in the recovery boiler that is needed to keep white liquor sulfidity to a level that will not affect the cooking selectivity. The recent development of the Black Liquor Heat Treatment process could offer a solution to this problem (Ryham and Nikkanen, 1992). This process removes about half of the sulfur in the black liquor as a gas, which bypasses the recovery boiler. This gas can then be converted to polysulfide or other useful forms. One full-scale Black Liquor Heat Treatment System is in operation, and the sulfurous gas conversion process is being developed. Anthraquinone also has the same impact on EMCC® pulp yield increases as it does on conventional pulps (Mayovsky, 1992).

Pulp Strength

Pulp viscosity is frequently used as an indicator of pulp strength. Most mills have a minimum acceptable viscosity below which the pulp's physical strength begins to deteriorate. Viscosity is a good relative indicator of the selectivity of the lignin-removing process, showing how well the cellulose is preserved at a given kappa level for a specific process. In relation to process changes associated with MCC® and EMCC®, many indications are that the minimum acceptable viscosity level will change to a lower number before the physical properties deteriorate (Elliott and Walley, 1991). To avoid confusion, the discussion that follows will focus on the pulp's physical strength properties — mainly its tear and tensile strength.

Pulp strength of lab-cooked EMCC® pulps from Southern pine is not affected until the kappa num-

ber from the lab digester is below 18 (Jiang et al. 1992b). Figure 11 shows the tear-tensile relationship for the fully bleached softwood pulps that were used for the yield determinations in Figure 8. The tear-tensile curves show no difference for pulps cooked to kappa numbers above 18 and then oxygen delignified to kappa numbers above 8. The kappa 12 pulp that was oxygen delignified to kappa 6.5 shows about a 20 percent reduction in tear at constant tensile, compared to the other pulps.

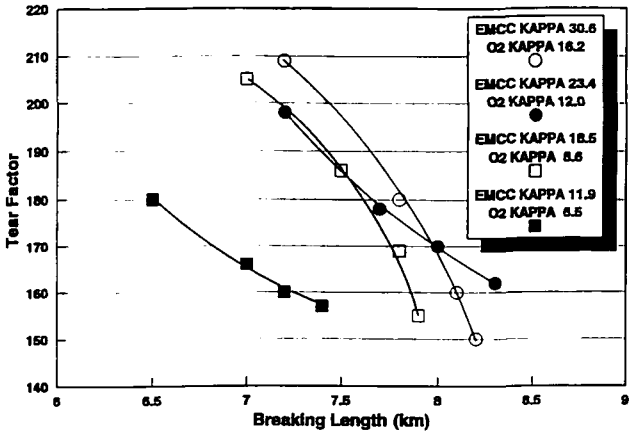

Figure 11.—Pulp strength for fully bleached EMCC®-O_2 pulps. (Tear factor versus breaking length.)

To determine the impact on pulp quality and effluent characteristics of low kappa pulping, trials lasting several days each were performed at Longview Fibre on West Coast softwoods (Elliott and Walley, 1991). The mill data showed no effect on the tear-tensile strength of the unbleached MCC® pulp down to about kappa 14, probably a 10 percent reduction in tear-tensile strength at kappa 12 and a definite strength reduction at kappa 8 (Fig. 12). Bleached sack paper produced from these same pulps showed no reduction in pulp strength until the unbleached pulp was about kappa 9. The mill does not normally operate at such low kappa levels because of the effect of yield

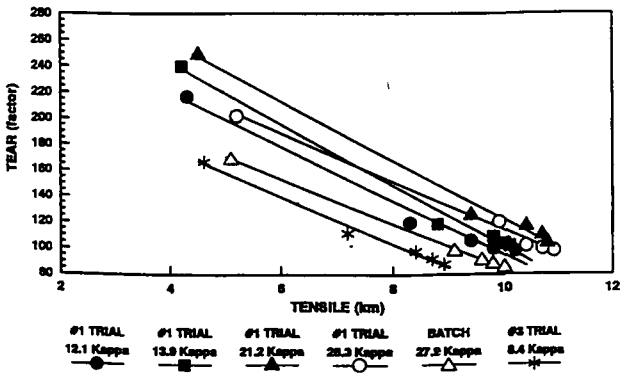

Figure 12.—Low kappa MCC® operation at Longview Fibre. (Tear-tensile comparison of low and normal Kappa unbleached pulp.)

loss on production capacity. Laboratory cooks on the mill chips showed that a 12 kappa pulp had a tear strength that was about 10 percent lower than 18 to 28 kappa pulps at constant tensile.

The differences in strength retention between the 12 kappa pulps made from Southern pine in the lab, West Coast softwoods in the lab, and unbleached and bleached West Coast softwoods in the mill compared to the higher kappa number pulps can have several explanations. Effects of species, testing procedures, testing accuracy, and lab and mill cooking and bleaching procedures are probably the most important.

Different pulp parameters are of varying importance to the makers of the vast array of products made from bleached pulp fibers. One set of process parameters would not be suitable for all types of bleached pulp from all types of wood sources. This difference could affect the optimum operating point for individual pulp mills.

Conclusion

In the laboratory, Southern pine can be cooked to kappa 18 using the EMCC® procedure, oxygen delignified to kappa 9, and bleached without total yield loss or physical strength loss, compared to kappa 28 pulps. Unbleached pulps of kappa 14 from West Coast softwoods have been produced in a mill without physical strength loss compared to kappa 28 pulps. Lower kappa pulps have been made with some strength loss and with a yield loss that is measurable in the mill. Capacity limitations in a mill resulting from the yield losses associated with pulping to lower than normal kappa numbers can have a major economic impact on an individual mill. Lab work has been performed to show yield improvements when polysulfide is added, but this process has had no mill applications as yet. The yield difference between different kappa numbers is maintained. MCC® and EMCC® have become widely accepted procedures for pulping to low kappa numbers.

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The Development of Chlorine-free Manufacturing of Bleached Kraft Pulp

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With collaborators MoDo and CIL, Sunds Defibrator Industries pioneered the development of oxygen delignification technology in the late 1960s and early 1970s. Our basic approach was to look for processes that increased delignification and increased recycling of dissolved lignin (Annergren and Näsman, 1980; Lindström et al. 1987; Nordén and Simonson, 1984; Hartler et al. 1983; Näsman and Sjödin, 1984).

Simultaneously, the pulp industry and research institutions began studying bleach plant effluents, with particular interest in their chemical composition and impact on receiving waters. Some effluent effects can be characterized as short-term and others as long-term. Short-term or acute effects are related to the presence of easily biodegradable material, often represented by the biological oxygen demand (BOD) value of the effluent. BOD causes oxygen starvation in the receiving water and can be acutely toxic, but it can also be handled in secondary treatment systems.

Long-term effects are not easily handled in secondary treatment systems because of the persistent character of some effluent components. Highly chlorinated low molecular mass organic material, caused by chlorine chemicals in bleaching is not very biodegradable and interferes with natural aquatic life processes.

The effluent's dark color, which decreases light penetration in the receiving water, is not affected by secondary treatment. These findings convinced us to develop processes that increase delignification, allow recycling of dissolved organic material, and minimize the use of chlorine chemicals.

The following technologies will offer these benefits:

- **Oxygen delignification** — More than 50 percent of kraft pulp production is processed in oxygen delignification stages, thereby decreasing the chemical oxygen demand (COD) in the effluent as much as 50 percent (Carré et al. 1986; Lindström, 1991).
- **SuperBatch™ cooking** — A recent development by Sunds Defibrator that decreases the lignin content of pulp significantly compared to conventional cooking. Mill scale trials have demonstrated that a lignin content corresponding to kappa numbers ranging from 10 to 12 can be reached via SuperBatch™ cooking as compared to about 30 for conventional cooking (Kovasin and Tikka, 1992; Hiljanen and Perala, in press).
- **CFree™** — A novel technology by Union Camp Corporation that applies ozone at high pulp consistency to produce pulps with very low lignin contents (Nutt, in press).
- **Hydrogen peroxide bleaching of kraft pulp** — A process pioneered by EKA Nobel that in combination with CFree™ produces fully bleached pulps without the use of chlorine chemicals (Andersson et al. 1992; Igerud and Basta, 1992).

The Conventional Kraft Fiber Line

A kraft pulp mill's target product is a bright pulp, suitable as raw material for manufacturing white papers and sanitary products among others. To

achieve maximum brightness, lignin is removed from the wood in the cooking and bleaching processes. But the cooking process removes part of the hemicellulose and cellulose-content of the wood and partly depolymerizes the remaining pulp. As this effect also occurs in the bleaching processes, the production of bleached kraft pulp has to be performed in several delignification and bleaching stages.

Economical pulp production requires that the cooking chemicals be recovered from the spent cooking liquor and recycled. A simplified representation of a bleached kraft pulp mill is outlined in Figure 1. Roughly 50 percent of the wood is dissolved in the cooking process. The dissolved wood substance and spent cooking chemicals are removed from the pulp in subsequent washing stages.

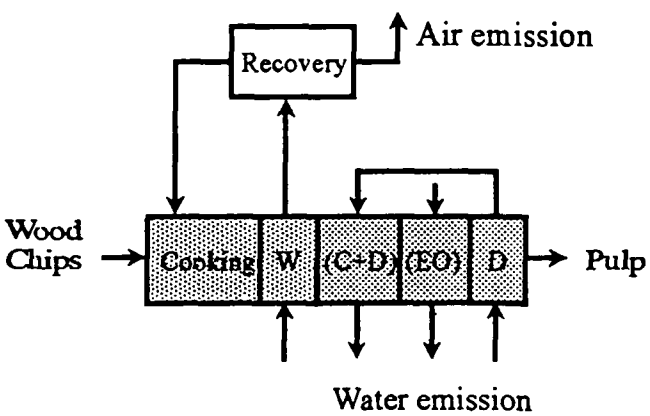

Figure 1.—Conventional kraft fiber line.

The black liquor obtained in this operation is concentrated and burned in a recovery boiler, generating heat and inorganic chemicals for further conversion to fresh cooking chemicals.

The final brightening of the pulp is performed in the bleach plant. Elemental chlorine (Cl_2) and chlorine dioxide (ClO_2) are the main chemicals used. It has not been possible to recycle and recover the bleach plant effluents to any significant degree because of the chlorides in these liquors. If these liquors were recycled with the black liquor, severe corrosion would occur, especially in the recovery boiler. In addition to the material dissolved in the bleaching process, the mill bleach effluent contains dissolved material from the incomplete washing of pulp prior to bleaching.

Oxygen Delignification

Oxygen delignification has been around for more than 20 years. The chemicals used in this process are oxygen, (O_2) and sodium hydroxide (NaOH), which are compatible with recycling. Thus, dissolved lignin can be recovered together with black liquor (see Fig. 2). A lower lignin content of pulp is thereby obtained (see Fig. 3), and less wood substance is dissolved in the bleaching process, decreasing the discharge of organic material by roughly 50 percent, analyzed as COD.

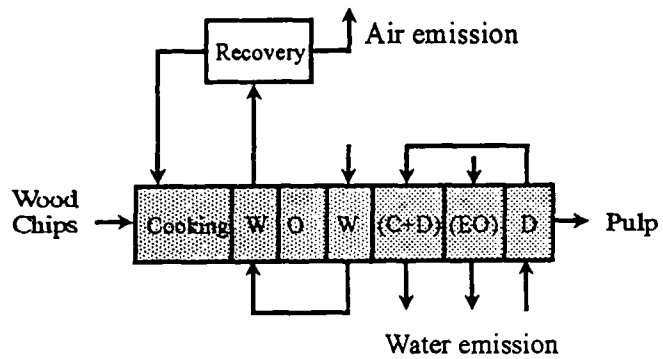

Figure 2.—Conventional kraft fiber line — oxygen delignification.

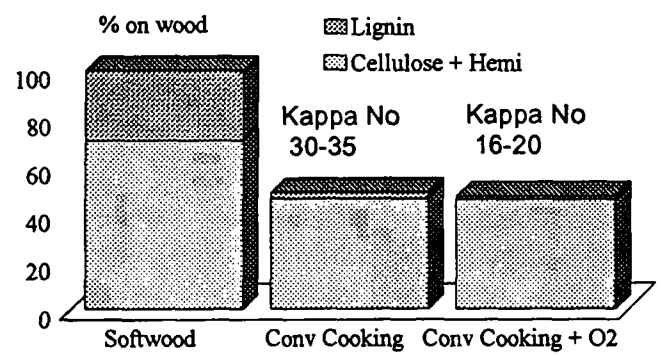

Figure 3.—Chemical composition.

For optimal performance, washing must be controlled before and after the oxygen stage. Dissolved material has to be washed out of the pulp prior to bleaching. This is done by washing pulp through two displacement wash presses.

Two different oxygen delignification systems are available today. One operates at high pulp consistency; the other, at medium pulp consistency. The medium pulp consistency systems dominate the industry, but in the last few years, three high consistency systems have been sold in North America.

The high consistency system, which was developed first, requires pressing the pulp to about 30 percent consistency. The reactor design and high pulp consistency causes a fluffy "bed" in the reactor, made from pulp fibers and surrounding oxygen gas.

The success of the medium consistency system results from improvements in mixing technology and intensive dispersion of the oxygen gas in the pulp matrix. The rate of reaction is slower in medium consistency oxygen delignification, re-

quiring about twice the retention time of the high consistency system. The simplicity of the medium consistency system — which doesn't have to control the carbon monoxide (CO) concentration in the gas phase — is attractive to the industry.

SuperBatch™ Cooking

The batch kraft cooking process remained virtually unchanged for about 100 years, until the 1950s, when continuous cooking technology gained acceptance. In the 1970s and 1980s, the technology advanced by stages, starting with a displacement and cold blow cooking technology at the ASSI Karlsborg kraft pulp mill in Sweden. Those changes were the basis for the SuperBatch™ cooking process.

Figure 4 is a simplified flowsheet of the cooking sequence. Conventional cooking has different initial procedures, and the final displacement and handling of the spent cooking liquor is also different. The SuperBatch™ technique has led to an unmatched improvement in the impregnation of wood with cooking chemicals.

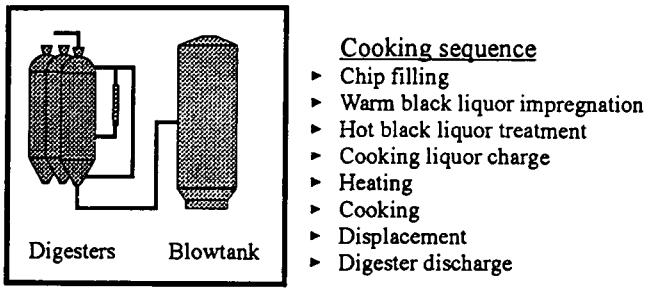

Figure 4.—SuperBatch™ cooking sequence.

By using the SuperBatch™ method, a more homogeneous and selective delignification is possible. This process results in lower kappa number variation and increased yield at a given final kappa number. Strength properties are also improved significantly. These benefits make it possible to extend delignifications beyond the normal practice in kraft cooking.

Figure 5 shows the effects on lignin content when conventional cooking is replaced by SuperBatch™ cooking or a combination of SuperBatch™ and oxygen delignification. Environmental benefits are shown in Figure 6. The combination of SuperBatch™ and oxygen delignification has the potential of decreasing the amount of organic material dissolved in bleaching by as much as 80 percent.

CFree™

Ozone delignification has been investigated in laboratory and pilot plant scale for years without commercial success. After 10 years of extensive research, however, Union Camp Corporation has recently experienced a technological breakthrough. This success resulted in the first commercial installation of a 900 tons per day system at Union Camp's Franklin Mill. Sunds Defibrator supplied the system, known as CFree™. This process will result in a dramatic 90 percent decrease of effluent-COD.

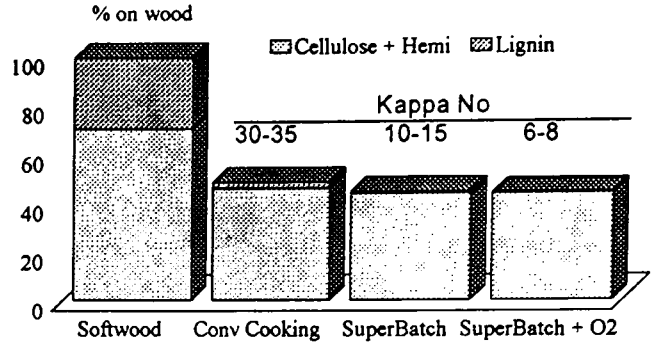

Figure 5.—Chemical composition.

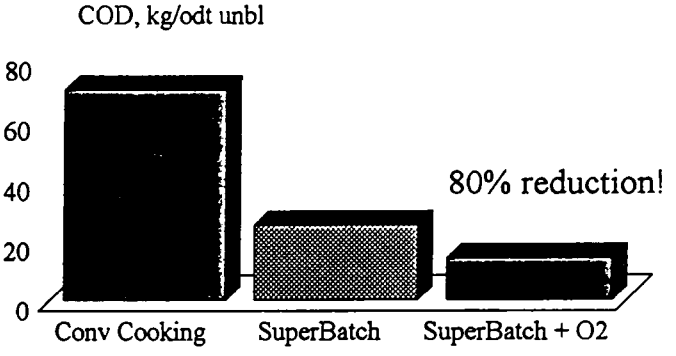

Figure 6.—Impact of SuperBatch™ and oxygen delignification on effluent-COD from bleaching of softwood kraft pulps.

The CFree™ process operates at atmospheric pressure and at high pulp consistency (see Fig. 7), which requires dewatering to the desired consistency in a twin roll press. Oxygen, used as a carrier gas for the ozone, is recycled to the ozone generation plant. An ozone stage can be installed to further decrease the lignin content of pulp prior to bleaching. Pulp with a very low lignin content can be achieved when SuperBatch™ cooking is combined with oxygen delignification.

Peroxide Bleaching

In 1989, EKA Nobel developed and introduced hydrogen peroxide (H_2O_2) bleaching, now known as LIGNOX™ bleaching, or oxygen delignified softwood kraft pulps aiming at brightness levels of 70 to 75 percent ISO. The pulp's end use has mainly been for reinforcement of newsprint, super calendered (SC), and lightweight coated (LWC) grades of paper. To qualify for woodfree printing and writing papers and high quality tissue, bright-

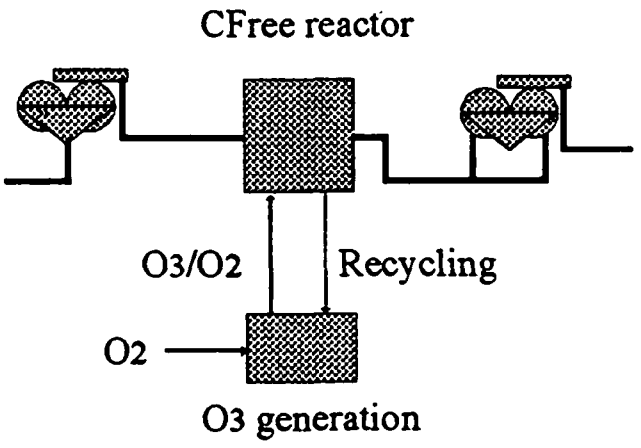

Figure 7.—CFree™ delignification system.

ness levels of 85 percent ISO have to be matched. But, EKA Nobel has demonstrated the potential of completely replacing chlorine chemicals in the bleaching of kraft pulps. Their work spurred intensive research efforts all over the world to further develop this technology.

The basic LIGNOX™ technology has a chelating stage prior to bleaching at medium pulp consistency with peroxide (see Fig. 8). The chelating stage and the subsequent washing of the pulp are of key importance in removing transition metals detrimental to the bleaching process. The LIGNOX™ technology can often be used in existing bleach plants with only minor modifications.

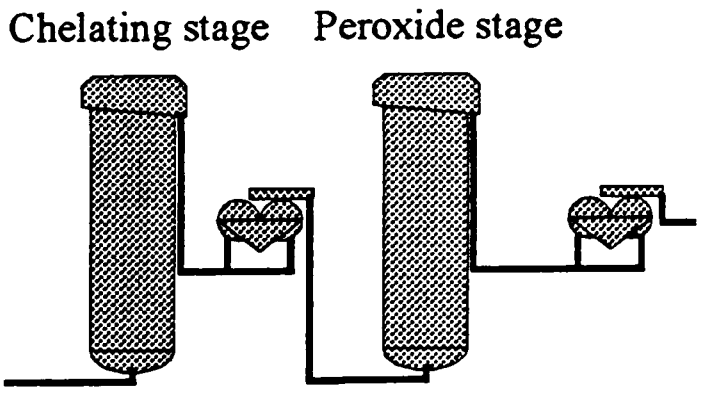

Figure 8.—Peroxide bleaching system — medium consistency.

In new installations, bleaching at high consistency should be considered, to improve the efficiency of peroxide bleaching. High consistency peroxide bleaching is a standard technology for bleaching mechanical pulps. It has not proved possible to recycle the spent liquors from these stages. One reason is the buildup of transition metals that occurs in the chelating stage. These metals can be carried into the peroxide stage and ruin its bleaching efficiency.

Today's challenge is to combine extended delignification in cooking and oxygen and ozone delignification with a final hydrogen peroxide bleaching. The result would be fully bleached softwood kraft pulps produced without the use of chlorine chemicals — a product already confirmed in laboratory delignification and bleaching of mill-produced SuperBatch™ softwood kraft pulp (see Fig. 9). In Figure 9, the bottom x-axis refers to sodium hydroxide (NaOH) in the oxygen stage, the middle and top x-axis refer to ozone and peroxide, respectively.

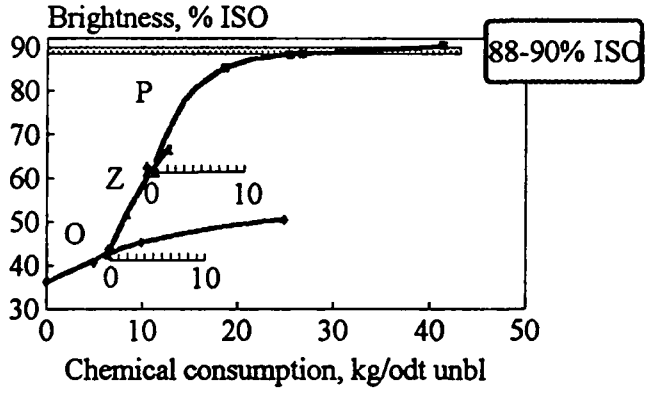

Figure 9.—Total chlorine-free bleaching of SuperBatch™ kraft pulp, Kappa 10.5.

By the end of 1992, all of these technologies will be up and running, but not yet combined into one kraft pulp mill system. What they can achieve in combination is previewed by two Swedish kraft pulp mills, currently operating with cooking systems similar to SuperBatch™ followed by oxygen delignification. These mills have reached final kappa numbers as low as 10. Extended mill runs applying the LIGNOX™ technology have also achieved brightness levels exceeding 80 percent ISO.

Concluding Remarks

The environmental benefits of the developments described in this paper are related to increased delignification and recycling of spent liquors. Thus, the resulting pulps will show lower kappa numbers compared with conventionally produced pulp. As the kappa number is decreased, a lower amount of organic material is dissolved in bleaching. A lower kappa number also makes it possible to decrease and eventually eliminate the use of chlorine chemicals in bleaching. The importance of reaching the low kappa numbers in the prevention of pollution is evident. All effluent parameters — chemical oxygen demand, biological oxygen demand, color and adsorbable organic halogens are decreased as

the kappa number decreases. However, in the case of the adsorbable organic halogens, the kappa number is less important than the reduction of elemental chlorine in the various stages of the process (Lindström, 1991).

The ultimate goal is to achieve total closure of the pulping and bleaching system.

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Recovery Boiler Capability to Accommodate Alternative Kraft Mill Processes

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The Technical Association of the Pulp and Paper Industry (TAPPI) sponsored a Paper Industry Research Needs workshop at the State University of New York, College of Environmental Science and Forestry in Syracuse, New York, May 26-28, 1992. The Pulping and Bleaching Processes Panel identified the major need in kraft black liquor recovery, namely, an affordable, incremental, chemical recovery capacity increase to remove the bottleneck in the recovery boiler operation. This paper will explore kraft mill process factors that cause a pulp producer to require more capacity. Approaches to removing the bottleneck and providing increased black liquor processing capability include retrofitting the existing recovery boiler to increase its capacity. Retrofit case histories were selected from an extensive list of retrofit experience to represent a spectrum of possible approaches.

Kraft Process and the Recovery Boiler

The kraft process diagram (Fig. 1) shows the typical relationship of the recovery boiler to the overall pulp mill operation. The primary function of a recovery boiler is to combust the black liquor produced in the pulping operation for the purpose of recovering the inorganic chemicals in the reduced form required for recycling to the digester. The heat content of the black liquor is recovered as steam for process heat and cogeneration electrical production. Electrical production is a secondary function, but an important economic consideration.

The kraft process starts with feeding wood chips to the digester. Chips are cooked under pressure in a steam heated aqueous solution of sodium hydroxide (NaOH) and sodium sulfide (Na_2S) known as white liquor, or cooking liquor. Cooking can take place in continuous or batch digesters. After cooking, pulp is separated from the residual liquor in a process known as brown stock washing. The most common method in use features a countercurrent series of vacuum drum washers to displace the liquor with minimum dilution.

Modern continuous digester installations incorporate a brown stock washing stage in the lower part of the digester body. Following washing, the pulp is screened and cleaned to remove knots and shives and to produce pulp for use in the final pulp and paper products. Currently, industry is focused on maximizing washing efficiency to recover chemicals, thereby reducing the chemical demand in the bleach plant.

The black liquor rinsed from the pulp in the washers is an aqueous solution containing wood lignins, organic material, and inorganic compounds oxidized during the cooking process. Typically, the combined organic and inorganic compounds are present at a 13 to 17 percent concentration of solids in weak black liquor. The kraft cycle processes this black liquor through a series of operations, including evaporation, combustion of organic materials, reduction of the spent inorganic compounds, and reconstitution of the white liquor.

The recovery boiler furnace (Fig. 2) was developed to combust the black liquor organic material while reducing the oxidized inorganic material in a pile, or bed, on the furnace floor. The

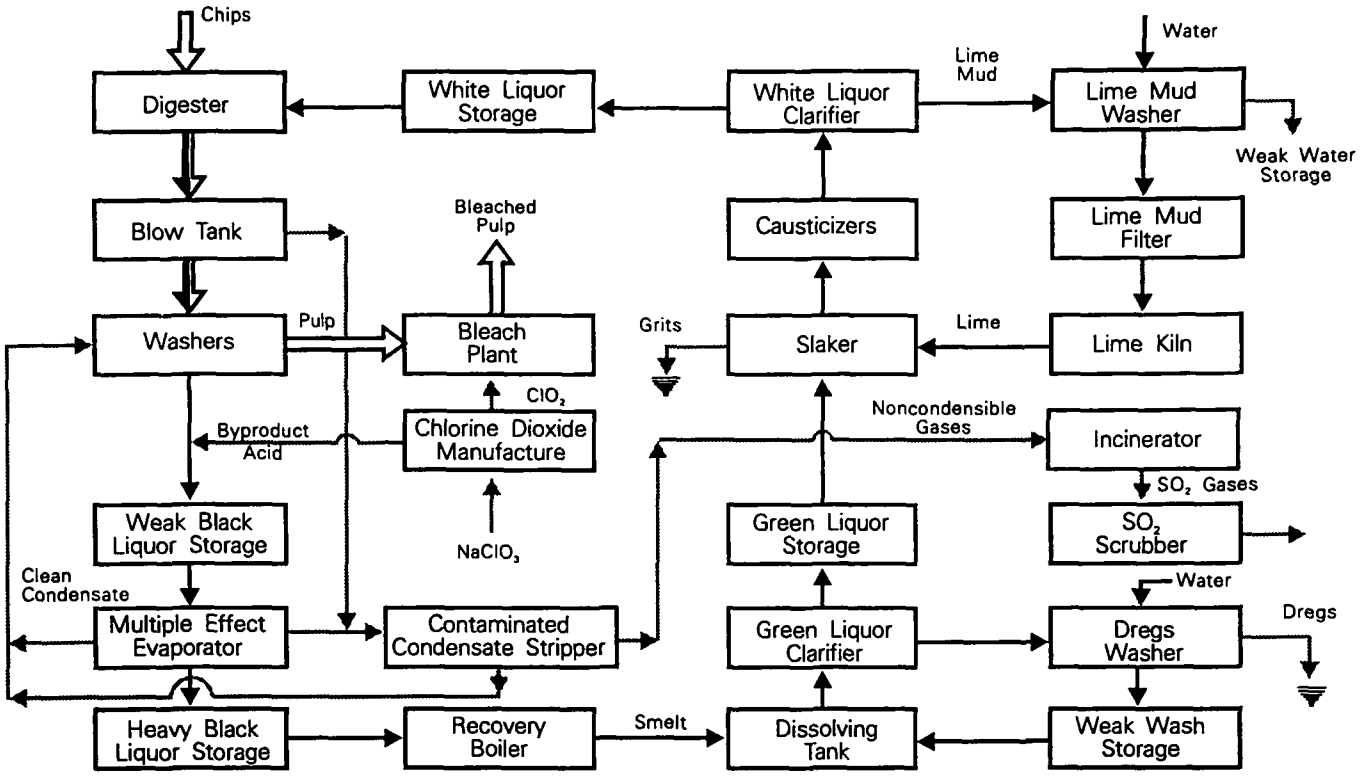


Figure 1.—Kraft process diagram.

molten inorganic chemicals, or smelt, are discharged to a tank in which they are dissolved to form green liquor. The active chemicals in green liquor are sodium carbonate (Na_2CO_3) and Na_2S. Green liquor is clarified to remove insoluble material, then reacted with lime (CaO) in a causticizing plant to convert Na_2CO_3 to active NaOH in the product white liquor.

Energy is released as the black liquor organic compounds are combusted, paralleling the reduction of sulfur compounds to form smelt in the recovery furnace. This combustion energy produces steam, which can be introduced to a turbine generator to supply a large portion of the energy demand of the pulp and paper mill. Steam extracted from the turbine at low pressure is reused in the process for cooking wood chips, evaporation, recovery furnace air heating, and drying the pulp or paper products.

Impact of Alternative Manufacturing Processes

Alternative kraft mill processes are increasing the quantity of organic and inorganic material in the black liquor that must be processed in the recovery boiler. Therefore, additional incremental capacity is required to recover the inorganic chemicals. In many mills, this capability is limited by the installed equipment.

Values for the increased capacity requirements are quoted from a 1992 report prepared for the Ontario Ministry of the Environment, which describes the impact on the recovery boiler throughput of alternative kraft mill processes (N. McCubbin Consultants, 1992). Several processes have been developed to extend delignification of the kraft pulps beyond the conventional levels. This extension is environmentally desirable in circumstances in which the pulp will be bleached in subsequent processes. "Extended delignification" is also known as "extended cooking." Delignification by oxygen, extended cooking, and improved brown stock washing and screening can produce up to 12 percent additional black liquor solids in a mill that has relatively high losses of black liquor solids in the sewer. In mills that already have good washing, defined as sodium losses under 10 kg of sodium sulfate (Na_2SO_4) per ton of pulp, the additional recovery load would be about 6 percent.

If the alternative processes are considered independently, oxygen delignification increases the solid flow to the recovery boiler about 4.4 percent, which represents a 3.3 percent increase in heat input. Applying extended cooking would increase the solids to the recovery boiler approximately 3 percent when the bleached yield of pulp from wood is maintained. The alternative of combining both oxygen delignification and digester-extended delignification, as well as efficient washing, could result in a drop in the yield of bleached pulp from wood, with corresponding increases in wood consumption and steam production. The combined changes to a mill operating with high losses could

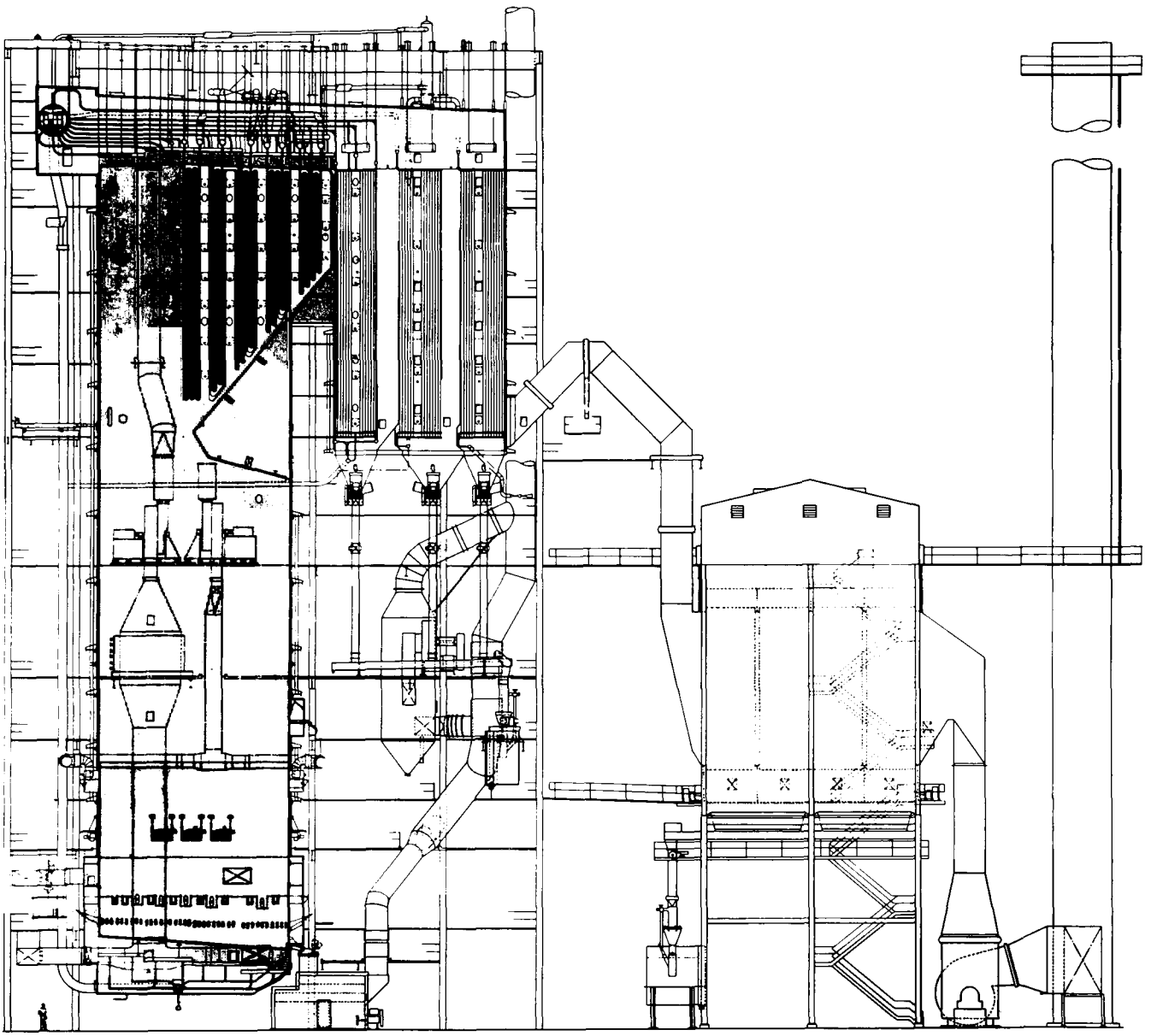


Figure 2.—Typical modern recovery boiler.

result in a 15 percent increase in solids to the recovery boiler and a 16 percent increase in heat input.

Chlorine dioxide (ClO_2) is used increasingly to replace the traditional chlorine in the first stage of the bleach plant. ClO_2 substitution is a simple approach to reducing organochlorines discharged from the mill. ClO_2 is always manufactured on the kraft mill's site since it is impractical to transport significant quantities. The ClO_2 plant is linked with the recovery process since the manufacturing process produces significant quantities of sodium-based by-product acid. It is general practice to blend the effluent acid from the ClO_2 generator into weak black liquor at a rate equivalent to the total sodium losses in the mill. In a modern mill with low sodium losses and practicing 100 percent substitution to produce a molecular chlorine free pulp, only about 25 percent of the by-product acid can be used. The excess must be neutralized before being discharged to the sewer; this effect is generally accomplished with lime.

Recovery Boiler Capacity

There are several ways to increase the recovery boiler capacity by 6 to 15 percent generally required by the combined application of oxygen delignification, extended cooking, efficient washing, and similar processes. Incremental capacity increases can also be measured in several ways. It can be an increase in the time between shutdowns to waterwash the recovery boiler, or, the capability to burn more black liquor without increasing the time (run campaign) between outages.

The most significant limiting factor to increased recovery capacity is ash buildup on the boiler heat transfer surfaces (Fig. 3). Low melting point, inorganic ash compounds formed in combustion of black liquor are borne upward by the gases in the furnace and stick to the surface of the tubes. As the black liquor throughput is increased, the increased temperature and velocity of the combustion gases increase the propensity of ash to stick and block the gas passages. Ash is cleaned from tube surfaces using jets of steam introduced through sootblowers.

Even with sootblowers in constant use to clean surfaces, the operator has no alternative but to shut down the boiler periodically and waterwash the tube surfaces. To accomplish this, the smelt bed must be totally removed and the boiler cooled. Total smelt bed removal precludes a possibility of water contacting molten chemical in the bed and producing a smelt water reaction. Interruption in operation for one to two days for waterwashing represents a potential loss in pulp production, or alternatively, continuing pulp mill production by shipping black liquor to an alternate mill site for burning, and purchasing the lost electrical generation from the utility. Downtime is an expensive proposition!

Therefore, the operator requiring additional capacity to process black liquor solids has two basic approaches to consider. The first is to add an additional recovery equipment line to process the solids. Alternatives to adding more lines are the focus of development projects. One alternative, a black liquor gasification unit installed at Frövifors in Sweden, is reported to have operated commercially for half a year (Boström and Hillström, 1992). The purpose of the installation was to increase the recovery boiler capacity by 75 to 100 tons of dry solids per day, corresponding approximately to an 8 to 10 percent increase in the capacity of the existing recovery boiler.

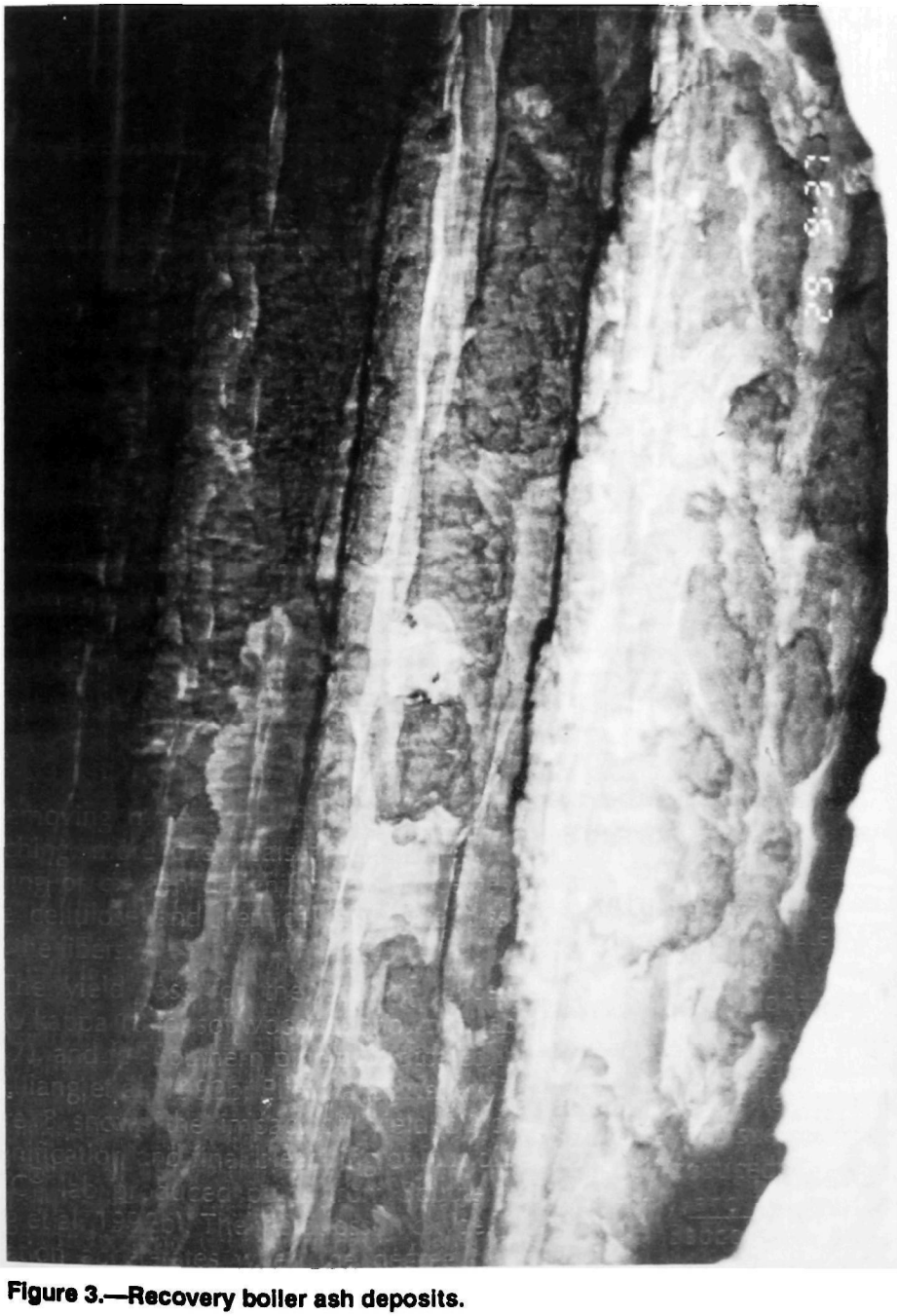


Figure 3.—Recovery boiler ash deposits.

Another solution to adding more lines is being developed by MTCI and ThermoChem and is based on pulse-assisted fluid bed gasification technology for indirect gasification of black liquor (Mansour et al. 1992). A design is reported to be under way of a 72 to 100 wet ton per day gasifier for demonstration testing at a southeastern mill. An incremental increase in capacity can be accomplished with a more traditional approach to combustion of black liquor by installing a modular unit similar to that installed at Millar Western Pulp Company in Meadow Lake, Saskatchewan (see Fig. 4). The boiler is designed to process 225 tons per day (or 496,000 lb per day) of dry solids.

The second way to achieve the required increase in black liquor throughput is the retrofit-

ting of a mill's existing recovery boiler. It is generally possible to retrofit a recovery boiler to increase capacity; however, in some mills, the boiler is already operating at its limit.

Retrofit Case Histories

An innovative project to increase recovery boiler capacity was completed in 1991 by Georgia-

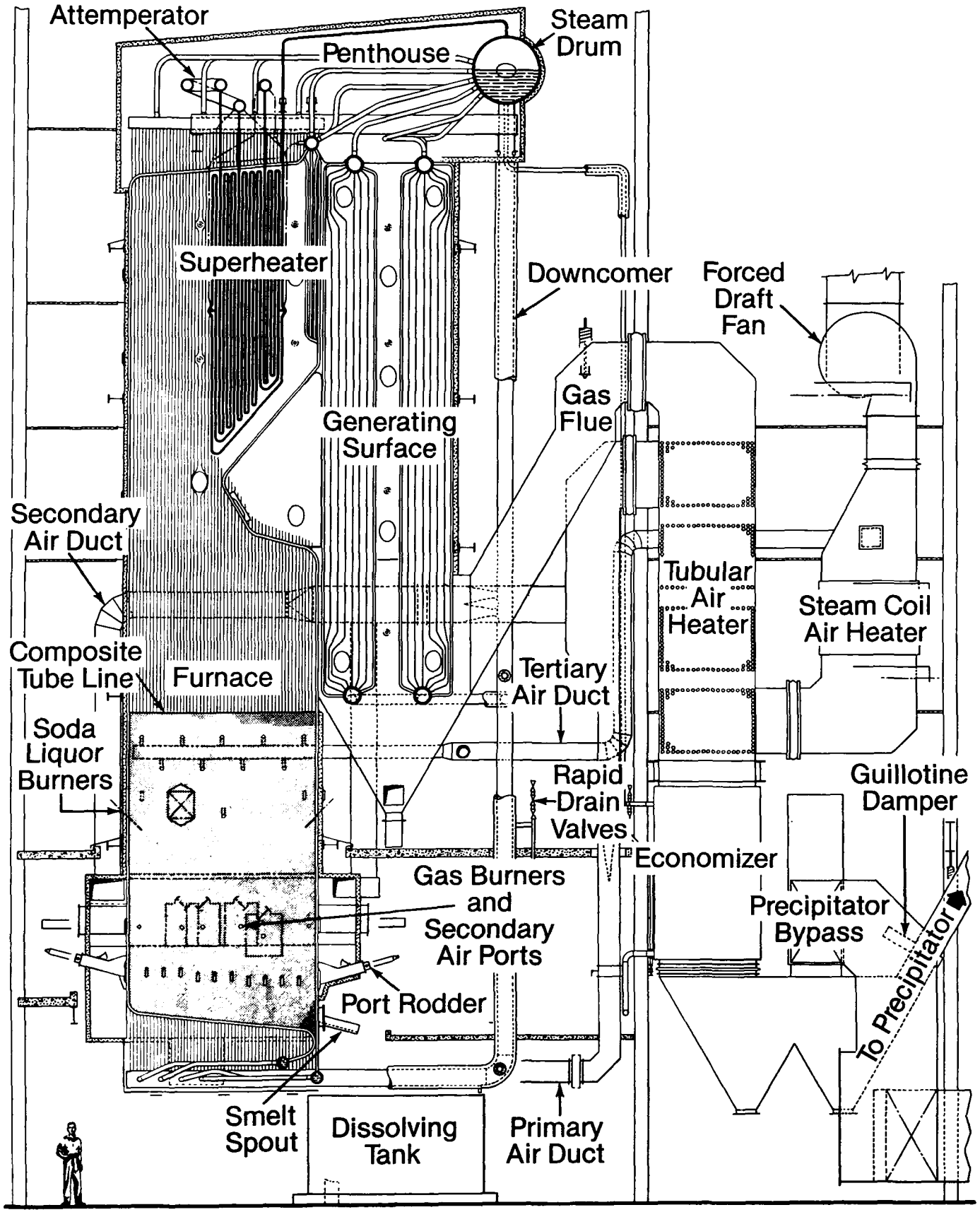
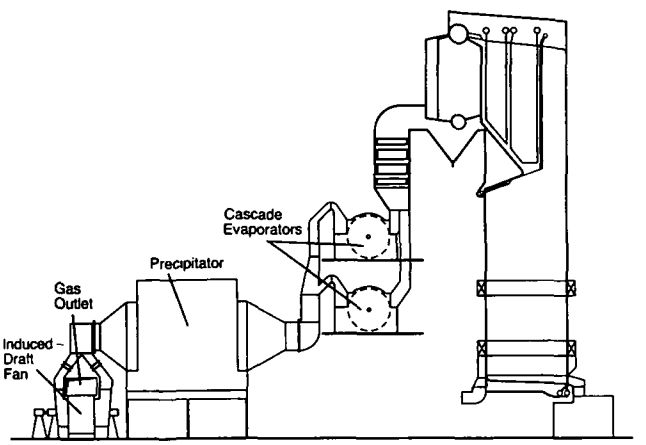
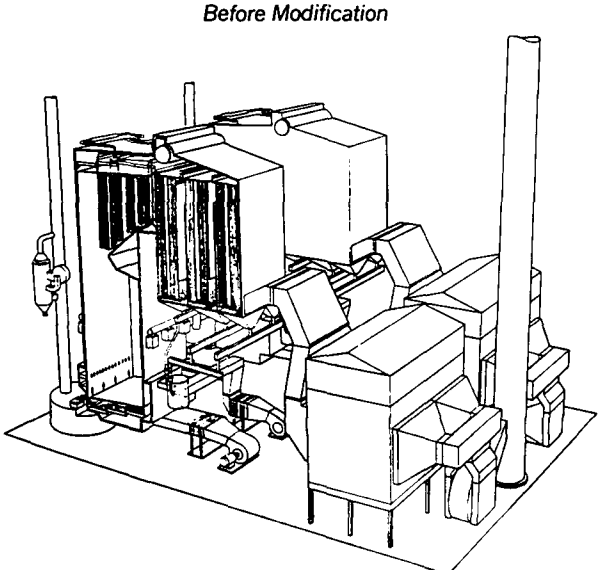


Figure 4.—Effluent recovery boiler.

Pacific at their Cedar Springs, Georgia, mill (Pedroso and Edwards, 1991). Two 1960-vintage recovery boilers were replaced with one drum modern boilers using the existing space, steel, and foundations to the maximum extent. The new boiler configuration provided a 22 percent increase in capacity. Elimination of the direct contact, black liquor evaporator accomplished a reduction in total reduced sulfur (TRS) emissions. Using a thoroughly planned construction approach, a 75-day outage (black liquor out to liquor in) was achieved for Unit 1, and 65 days for Unit 2. Figure 5 shows the boiler and equipment configuration before and after the upgrade.



Before Modification



After Modification

Figure 5.—Georgia-Pacific.

An incremental capacity increase can be achieved with a more modest approach to a retrofit program. Capacity improvements are presented as black liquor solids rate, but, it should be understood that recovery capacity is rated in heat input. Some of the increases in black liquor solids throughput may be the result of operating at a lower heat value than was used in the original design. Nevertheless, they are indicative of the incremental increases that can be achieved through various programs.

Case History No. 1

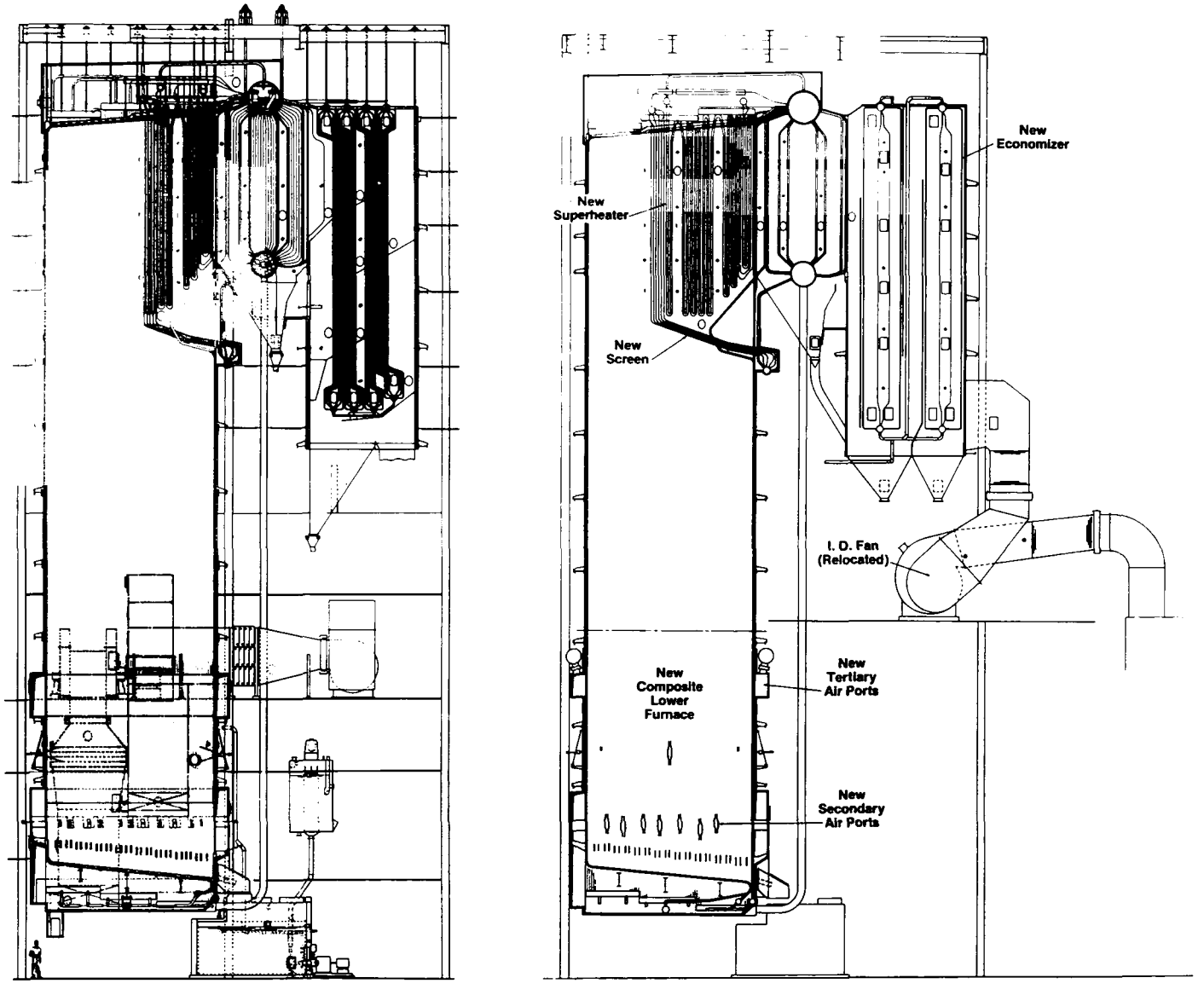
The capacity of the recovery boiler at Stone Container Corporation in Florence, South Carolina, was limited by buildup of ash deposits in the economizer. Frequent outages were required to waterwash the economizer. The operator acquired an increase of 10 percent in liquor solids capacity and conversion of the recovery unit to low odor by eliminating the direct contact evaporator. Babcock and Wilcox provided engineering, material and construction to modify the boiler to achieve the increase in solids throughput. Modernization included

- a state-of-the-art, three-level air system;
- modified liquor firing system;
- additional superheater surface to maintain the temperature of steam; and
- an extension of the building to accommodate the new long flow economizer.

For maintenance purposes, the lower furnace and boiler bank were replaced. The lower furnace was replaced with modern composite tube construction and the boiler bank was retubed. In addition, the larger superheater required a new screen. The configuration before and after modifications is shown in Figure 6. The boiler was started in 1991, and the retrofit proved successful.

Case History No. 2

Potlatch Corporation in McGehee, Arkansas, obtained a 63 percent increase in solids processing capability when Babcock & Wilcox enlarged the furnace and added a new three-level air system as shown in Figure 7. The furnace depth was increased five feet for the entire height of the furnace. The increase in furnace size resulted in a solids increase from 680 tons per day (1.5 million lb per day) to 1,111 tons per day (2.45 million lb per day). Steam flow increased correspondingly by 54 percent. The steam flow increase resulted in part from the customer's decision not to modify the superheater surface, offset by a lower than rated solids heating value. The unit operates at a lower steam temperature, decreased from the initial design temperature of 440°C (825°F) to 392°C (737°F). The capacity increase was completed in early 1992.



Before Modification

After Modification

Figure 6.—Stone container.

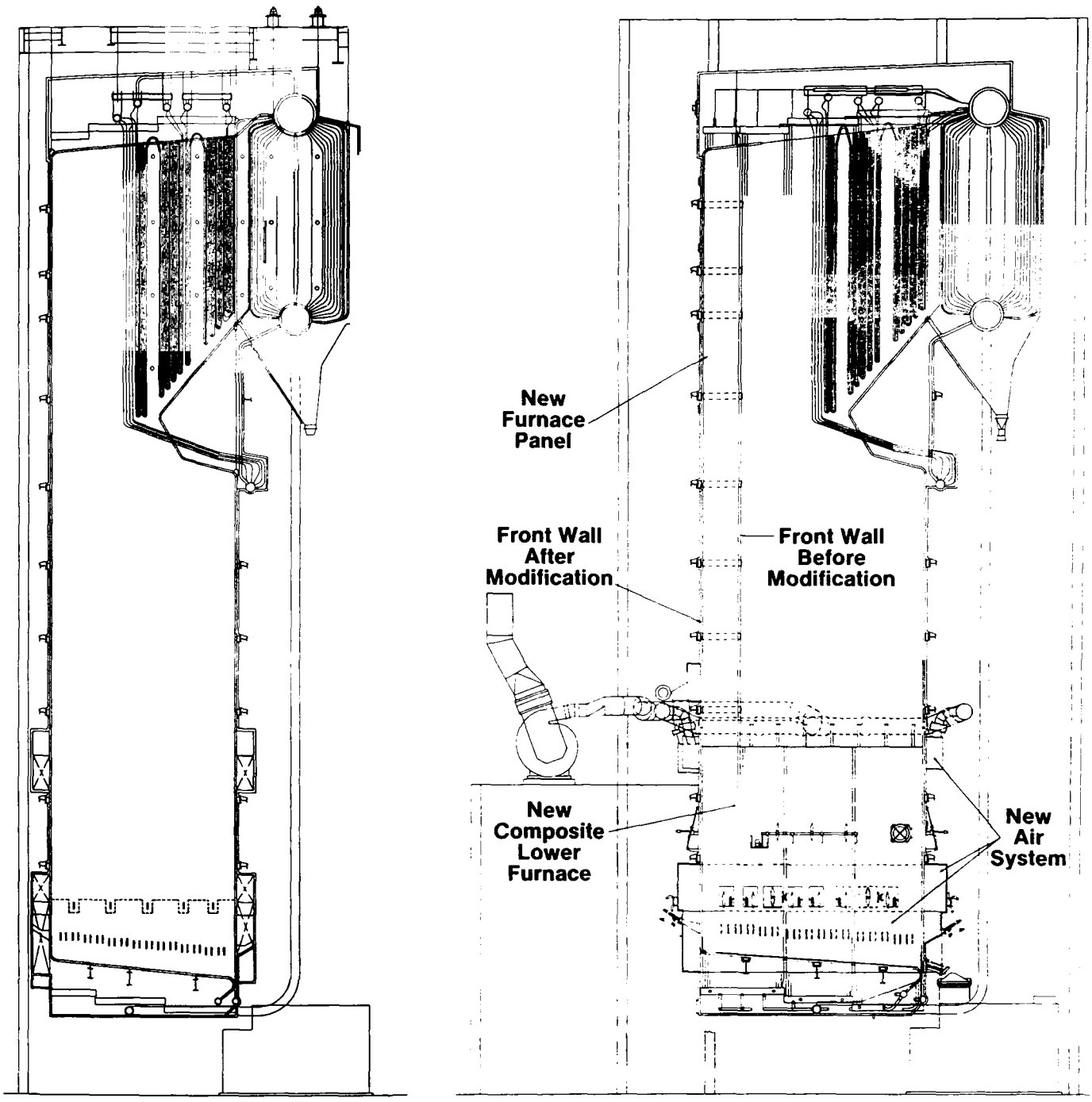
Case History No. 3

Gaylord Container Corporation at Bogalusa, Louisiana, wanted to increase the time between six-week waterwash intervals on an overloaded recovery boiler while also reducing the TRS emissions from the stack. The boiler, rated at 1,043 tons per day (2.3 million lb per day) of black liquor solids, was operating at 1,270 tons per day (2.8 million lb per day). Final air flow modifications completed in June 1988 resulted in reduced TRS emissions coinciding with extending the interval for waterwashing to beyond six weeks. The final air system modification introduced secondary air from furnace sidewalls only and tertiary air from the front and rear walls. Babcock and Wilcox's port design for interlaced air jets was maintained at both levels.

The success of this project encouraged additional modifications to achieve a significant overload at 1,451 tons per day (3.2 million lb per day) of solids. The upgrade involved changing the superheater and removing every other row of generating bank tubes (see Fig. 8). The unit proved capable of operating at a significant overload of 28 percent over the original heat input rate for six months between waterwashings.

Case History No. 4

The retrofitting of the boiler at James River's St. Francisville, Louisiana, mill was driven by the State of Louisiana's requirement to bring boiler operation into compliance with emission standards, necessitating a conversion to a low odor arrangement. James River also required an additional 23 percent



Before Modification *After Modification*

Figure 7.—Potlatch.

solids processing capacity. The unit was originally designed to process solids at a rate of 816 tons per day (1.8 million lb per day) and routinely operated at 998 tons per day (2.2 million lb per day). To achieve 1,224 tons per day (2.7 million lb per day) of dry solids processing capability, the furnace volume was increased to that required to process the desired solids by adding seven feet to the furnace depth and nine feet to the height (Fig. 9). A new combustion air system with interlaced tertiary air ports supplied with high static ambient air and interlaced secondary air ports was also incorporated. Other modifications included a new superheater to restore the original steam temperature; additional black liquor burners for operating flexibility; and additional sootblowers arranged to efficiently remove ash deposits from the heat transfer surfaces. The odor compliance was achieved by replacing the direct contact evaporator with a long flow economizer to cool the gases prior to discharge.

Two years of planning went into the capacity increase and low odor conversion. A team effort by James River with Babcock & Wilcox resulted in a fully integrated project program with detailed engineering governed by feasibility of construction. The intensive effort resulted in the entire project being completed in a 49-day outage, seven days ahead of the forecasted downtime, and within budget. The retrofit relieved a significant capacity bottleneck while satisfying emission requirements.

Conclusion

Alternative kraft mill processes are incrementally increasing the quantity of black liquor solids that must be processed in the recovery boiler. Although

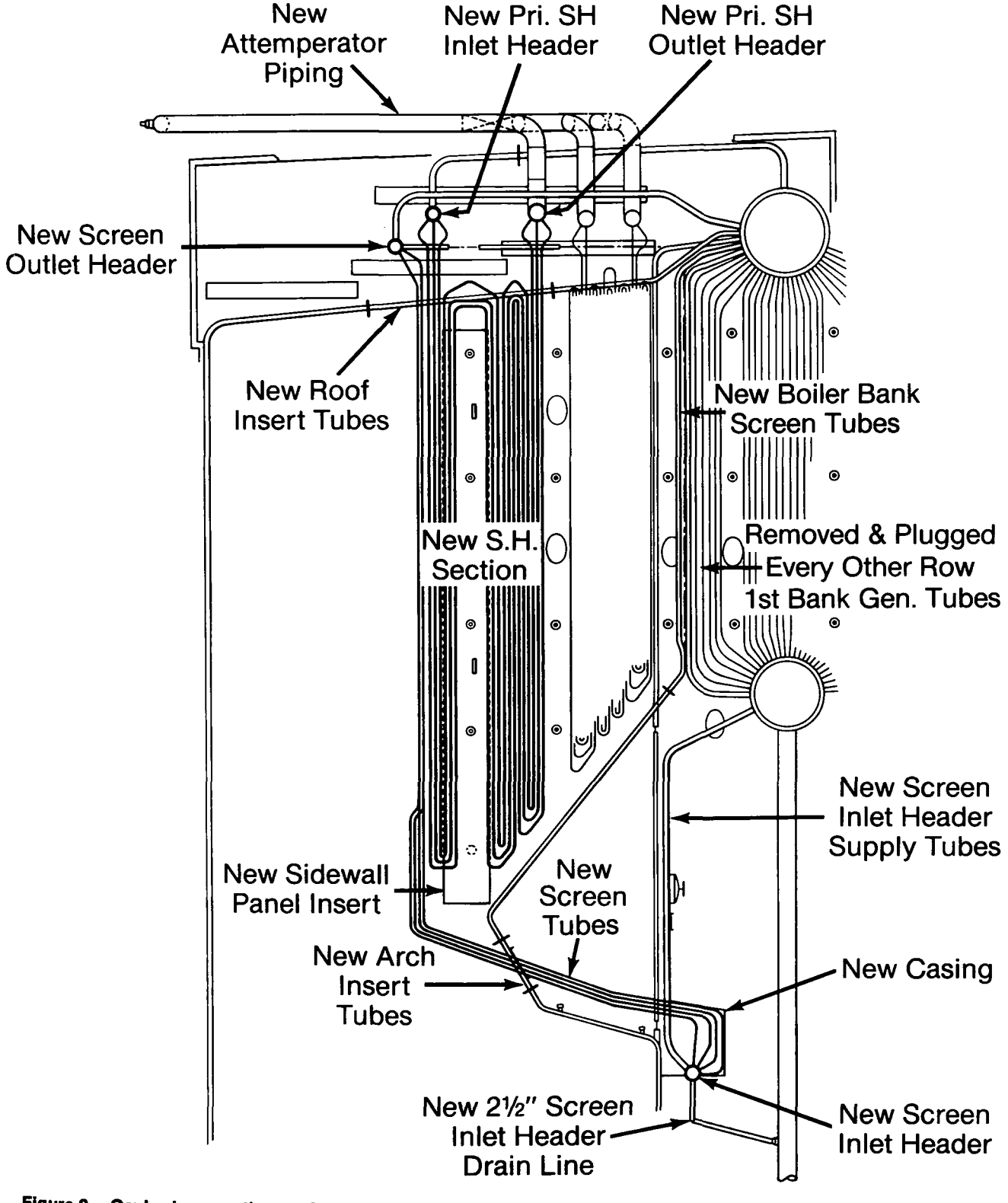
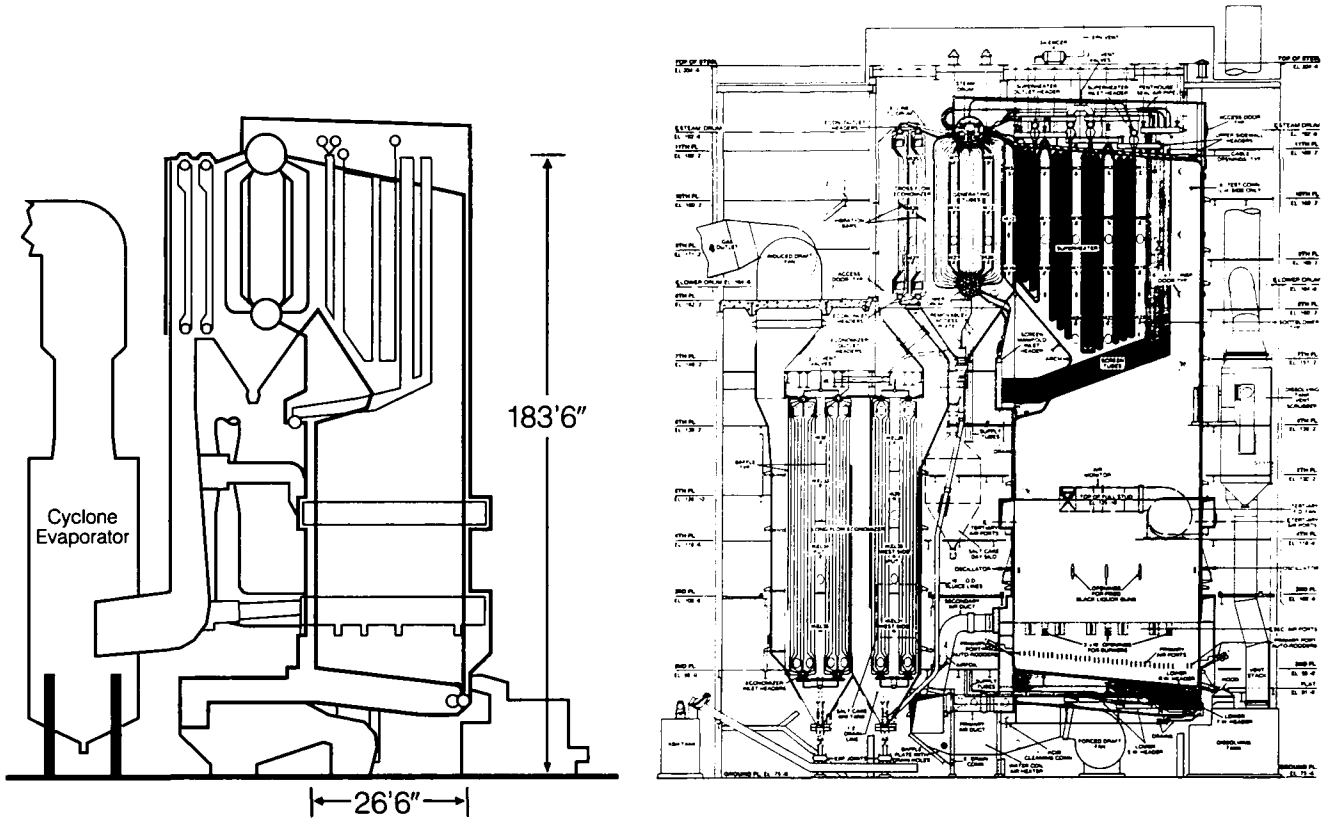


Figure 8.—Gaylord convection surface modifications.



Before Modification *After Modification*

Figure 9.—James River.

a number of approaches to increasing a mill's black liquor processing capability exist, no one solution fits every situation and each must be studied to ascertain the most economical approach. The new technologies should be investigated as an alternative to processing the increased solids in the existing recovery boiler or boilers. While the retrofitting of an existing recovery boiler is an attractive option, feasibility and cost need to be determined. In many cases, the retrofitting of a recovery boiler can achieve a capacity increase exceeding the requirements imposed by alternative processes.

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Alternative and Emerging Nonkraft Pulping Technologies

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Invented more than 100 years ago, kraft pulping has gradually achieved dominance in the pulp and paper industry as a result of continued refinements. Since 1950, many processes have been proposed to replace kraft pulping, but few have received even a single mill trial, and even so, it is a big step from a laboratory demonstration to commercial reality. Most competing processes have failed to do sufficiently well in pilot trials to convince investors to go ahead at full scale. Their failure does not mean that the kraft process will always be dominant, but it indicates the extreme effort and cost that is involved in commercializing any alternative to this established and versatile pulping technique. New refinements to the kraft process, such as extended delignification, made it even more attractive.

This brief review covers the main competitors to the kraft process for the production of chemical pulp — the sulfite processes, soda-anthraquinone (AQ) pulping, and the solvent pulping processes. The processes selected for discussion are commercially proven, or at least have had extensive plant trials.

Sulfite Processes

The sulfite processes provide pulps that have inferior strength properties to those of kraft pulp but which nonetheless are enjoying some success in the European marketplace because, unlike kraft pulp, they respond well to bleaching with hydrogen peroxide. Totally chlorine-free (TCF) softwood sulfite pulps having an 80 percent ISO brightness are easily obtainable, and 86 percent brightness aspen pulps can be produced by bleached chemithermomechanical pulp (BCTMP) mills.

Low Yield Sulfite Pulping

No modifications to the pulping process have been required for the production of TCF pulps in sulfite mills — it was sufficient only to switch the bleach plant to peroxide bleaching. Often a single peroxide stage is sufficient to produce the required brightness. A significant market for this kind of pulp exists in Europe; it is currently supplying all the primary fiber used by the German tissue industry, according to an article in a May issue of *Pulp and Paper Industry This Week* (1992). However, the TCF pulp market was not strong enough to keep alive one Canadian mill (Fraser Co., Atholville, New Brunswick) that was capable of producing 120,000 tons per year of peroxide-bleached sulfite pulp until it closed in 1991. Many papermakers cannot accept the lower strength of sulfite pulp — particularly those making lightweight coated and super calendared (SC) grades. For them, sulfite pulp is not an alternative.

Bleached Chemithermomechanical Pulp

BCTMP is cheaper to produce than low-yield sulfite and, in the case of Millar-Western's Alkaline Peroxide Pulping (APP) process, can be obtained at a high brightness right from the chip refiner. Other BCTMP installations postbleach CTMP with hydrogen peroxide. Since BCTMP generally sells at prices 15 percent below the price of comparable kraft pulp, papermakers are interested in trying it as a kraft substitute and BCTMP is moving into coated wood-free grades and printing and writing papers in Europe (*PPI This Week*, 1992). Apart from the strength deficit of softwood BCTMP compared to softwood kraft pulp, the main disadvantage of this pulp is that it contains lignin. The lignin causes brightness reversion when BCTMP-containing

paper is exposed to light. This reversion is inhibited, but not totally eliminated, in coated grades.

Closed-cycle Pulping

The Millar-Western Company recently began operations at its new closed-cycle BCTMP mill at Meadow Lake, Saskatchewan, Canada (Evans, 1992). Within three months, the mill reached 95 percent of its target production — a phenomenally successful start-up. If the mill continues to perform in this way through the end of 1992, the feasibility of closed-cycle operation for CTMP mills can be considered proven.

The profitability of closed-cycle operations is something else; no cost figures are available for the Meadow Lake mill, but these are expected to be somewhat higher than conventional BCTMP using the same wood furnish because of the elaborate water treatment plant required. Water use has been kept very low at Meadow Lake, but 13 cubic meters of water have to be evaporated for every ton of pulp produced. This compares with about 10 cubic meters per ton that evaporated from black liquor in an average kraft mill. The difference is that a kraft mill has plenty of steam from the recovery boiler to drive the evaporation, whereas closed-cycle BCTMP mills use electric power to operate the evaporators (or crystallizers).

■ **How Far Off Is a Closed-cycle Kraft Mill?** To answer this question, we must first recognize that we are dealing with two different problems — closing an existing kraft mill, or building a greenfield closed-cycle kraft mill. The key factor for closed-cycle operations is water consumption, which must be brought to an absolute minimum if the economics and logistics of running with a closed loop are to be acceptable. There is little chance that any of the older pulp mills will be closed — water consumption is too high (see Table 1). Even many pulp mills of modern design, such as the Riocell mill in Brazil, still have effluent flows amounting to three times the evaporator load at Meadow Lake.

Table 1.—Effluent volumes discharged by pulp mills.

	m^3/ADMT	US gal/ADT
BCTMP Mills		
Whitecourt, Alberta	22	5,300
Meadow Lake, Saskatchewan	12–14*	2,900–3,400
Kraft Pulp Mills		
Older mills	80–300	19,000–72,000
Alberta Pacific, Alberta	~58	~14,400
Riocell, Brazil	40	9,600
Ngodwana Kraft Mill, Republic of South Africa	8–10**	1,920–2,400

*This effluent is discharged to a holding pond and completely recycled.
**This effluent is used to irrigate grasslands.
ADMT = air-dried metric ton
ADT = air-dried ton

So it appears that with one exception, only greenfield kraft mills are serious candidates for closed-cycle operations. The Ngodwana Mill in South Africa was specially built for low water use (Coetzee et al. 1985) and represents an example of the type of kraft mill that could be closed, but it is unique. Besides controlling water volume, other steps must be taken before a closed-cycle kraft mill can be operated; for example, we need to minimize the chloride ions in the liquor loop. Pitch and non-process elements also need control.

Note that Meadow Lake has a purge of non-process elements because it is not presently recovering its pulping chemicals. That option, however, is not feasible for a kraft mill.

Hardwood Pulps

Soda-anthraquinone

This pulping process, although an alternative to kraft pulping, is not exactly emerging; it has emerged and stalled. First proposed in 1977 (H.H. Holton's U.S. Patent 4,036,681; see also Holton, 1977), soda-AQ pulping techniques are used in roughly a dozen hardwood mills around the world. The process is sulfur-free and works best with short-fibered hardwoods and annual plants. It is extensively used in India and China in small operations pulping bagasse, bamboo, and straw.

Practically all the existing soda-AQ mills are modifications of earlier soda cooking operations. Anthraquinone brings benefits to a soda mill in terms of pulp strength, cooking rate, and yield, thus compensating for the AQ cost. To my knowledge, none of the current soda-AQ operations were originally kraft mills. Conversion of a kraft mill to soda-AQ offers no rate or yield improvements and, for long-fibered furnishes (softwood and eucalyptus), soda-AQ pulps are definitely weaker than kraft pulps.

In contrast, for short-fibered hardwoods, soda-AQ pulping offers a proven sulfur-free alternative to kraft pulping that does produce an acceptable product. Conversion of an existing kraft mill to soda-AQ would entail capital and operating expenditures to expand the output of the lime kiln and the recausticizing units by 20 percent. On the positive side, smoother recovery boiler operations can be anticipated in the fully oxidizing soda furnace, leading to higher throughput.

After the AQ cost has been deducted, the improved recovery operations could provide a positive

return on the investment. Since no kraft mills have made this switch, we can assume that the return on investment is not high enough. For a greenfield mill, the size of the recausticizing unit would not be an issue; however, since no greenfield soda-AQ mills have been built recently — only kraft mills — the economics of greenfield soda-AQ mills are evidently not impressive either.

Alcell® Pulping

In this technique, hardwood chips are exposed to an acidic (pH 4) alcohol-water mixture at 195 °C (400 pounds per square inch gauge), which degrades and dissolves lignin and produces hardwood pulps at about 30 kappa. Much of the residual lignin can be removed by an alkaline extraction. Oxygen delignification is particularly effective for that purpose. Alcell® pulp strength is similar to that of kraft hardwood pulps from the same species (Petty, 1989), and some characteristics, such as opacity, are often superior. True solvent processes, like Alcell®, do not use recovery boilers since there are no inorganic materials to recycle. After the solvent has been flashed off, lignin precipitates from the aqueous component of the pulping liquor, leaving a carbohydrate solution.

The carbohydrate solution should be rather easy to dispose of as a cattle feed supplement, but the lignin is an important component in the mill's economics and represents both a challenge and an opportunity for the true solvent processes. The absence of a recovery boiler (a big saving in capital cost) means that the true solvent techniques are heavy net energy consumers; therefore, the lignin by-product must be credited with sufficient value to cover these energy costs. Lignin must be used for something other than hog fuel. Herein lies the challenge — to find new uses for lignin, for example, as a binder or resin extender.

Since true solvent lignins are free of sulfur and sodium, they are well suited to developing the special market niches that would be needed to establish the first North American solvent mills.

The absence of a recovery boiler means also that Alcell® units should be economically viable at a scale of about 300 tons per day, and units processing 550 tons per day are said to offer the same return on investment as a world-scale (1,200 tons per day) kraft mill. The small scale should make Alcell® pulping attractive in situations of limited wood resources or capital availability. Another possibility is the addition of solvent pulping units alongside existing kraft mills, perhaps providing a hardwood furnish component so that a softwood pulp mill can become integrated with papermaking operations. In this case the existing kraft recovery furnace could possibly be used to recover the effluent from the oxygen stage in the solvent pulp bleachery.

Alcell® has practically completed its trials in a batch pilot plant running at about 15 tons per day. Larger scale trials are now contemplated in order to demonstrate improved recovery efficiencies for the ethanol solvent (Maddern, 1991). As happens with most new technologies, Alcell® is likely to begin commercial production in a niche market — producing special grades of lignin and a bleached hardwood pulp that may at first be captive. Whether Alcell® becomes a serious competitor to hardwood kraft mills will depend on controlling solvent losses and making process refinements, expanding the markets for lignin, and — not least — the efficacy of refinements still occurring in kraft pulping.

Softwood Pulps

Alkaline Solvent Processes

The two main alternatives to kraft in this category are emerging in Germany. No kraft mills were ever built in former West Germany because of concern over odor problems and boiler safety. Germany has an abundance of softwood, and while German sulfite mills have thrived on pulping spruce, much pine wood was exported. Some of this fiber was later reimported from Scandinavia or Austria in the form of bleached kraft pulp. As a result, a sizeable effort has been underway in Germany for many years to develop a process for converting the native softwoods to pulp of kraft quality without using reduced sulfur compounds.

Two solvent pulping processes have been extensively researched at pilot scale and one will soon be in commercial operation. Both use alkaline conditions, which so far seem to be essential to produce high strength softwood pulps.

Organocell

The Organocell process, soon to begin commercial operations (430 tons per day of fully bleached fluff pulp) at Kelheim, uses a soda-AQ-methanol cook to obtain a pulp with a strength somewhat below that of kraft but eminently suitable for fluff pulp. The Organocell mill resembles a kraft mill in many respects, except that the continuous digester vessel has thick walls to withstand the extra pressure from the methanol vapor. The recovery furnace will be run in a fully oxidizing condition with very little smelt but a heavy carryover of the sodium carbonate ash (thus it will need an oversized electrostatic precipitator). The mill also has a methanol

recovery unit, and the bleach plant is planned to be chlorine-free with a medium consistency ozone (OZP) sequence.

The capital cost of greenfield Organocell mills will be about the same as that of a conventional kraft mill. Although it needs high-pressure equipment, flame-proof electrical gear, and methanol recovery units, compensation is obtained in the form of a smaller, cheaper (fully oxidizing) recovery furnace (Murrinen et al. 1989).

Organocell operating costs, however, will exceed those of kraft because of the need for nitrogen padding, AQ addition (which adds about $17 per ton of pulp), and increased lime usage. Extra power and steam will be required to operate the methanol recovery, but no makeup methanol is anticipated. That is because methanol is generated during alkaline pulping and is expected to balance the solvent losses.

Alkaline Sulfite Anthraquinone Methanol

Alkaline sulfite anthraquinone methanol (ASAM) pulping is the only emerging pulping process that can produce softwood pulps that consistently exceed kraft pulp strength (Zimmerman et al. 1991). The pulps' viscosities are remarkably high because of the low alkalinity at which the cooks are carried out (Kordsachia, 1988; Zimmerman et al. 1991). They also have good bleachability (Zimmerman et al. 1991) and can be cooked to low kappa numbers (Patt et al. 1990).

The disadvantages are in the cost of liquor preparation and chemical recovery. Besides the usual additional costs associated with solvent pulping (pressure vessels, flame-proof items, nitrogen padding, solvent rectification column), ASAM also needs a full sulfite recovery system plus a Tomlinson recovery boiler, lime kiln, and recaust unit (Fuchs et al. 1991). In fact, ASAM needs three separate recovery loops (see Fig. 1) to recover methanol, caustic, and sodium sulfite. Even though the lime kiln and recaust unit can be much smaller than for kraft, the additional items are expected to raise the capital cost of an ASAM plant 10 to 20 percent above that of kraft (Maddern, 1991).

Operating costs at first sight also appear to be higher; the AQ alone adds about $17 per ton of pulp to operating costs. The inorganic chemical charge and the digester operating temperature are also higher, both of which increase the operating costs compared to kraft. However, much of the increase is compensated by the higher bleached yield of ASAM pulp (45.5 percent vs. 43.5 percent). These yields are calculated from data in Zimmerman et al. (1991) after allowing for recooking of rejects.

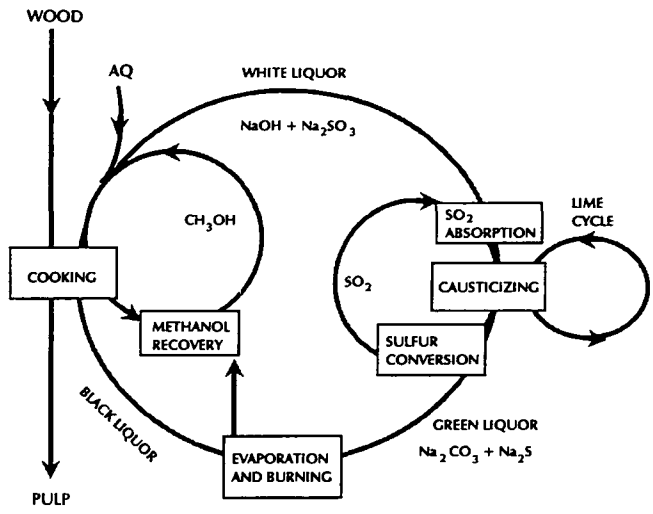

Figure 1.—Chemical recovery cycles for an ASAM pulp mill.

Though ASAM makes excellent pulp, this process is definitely the most complex of the emerging technologies. The capital cost is likely to be quite high. Operating costs are also likely to exceed kraft costs unless TCF pulps are being produced, in which case ASAM's low kappas and good bleachability become very significant.

Conclusion

The kraft process has gradually risen to dominance as a result of continual refinements. There have always been competing processes that looked good at laboratory scale but few managed to remain promising after extended plant trials. Of the six competing processes discussed here, none seems destined to replace kraft as the major source of virgin chemical pulp for papermakers.

Soda-AQ pulping will be restricted largely to nonwood pulping and a handful of hardwood mills. Once nonchlorine bleaching of kraft pulp is made cheaper, acid sulfite pulping will lose its only current advantage over kraft. BCTMP will continue to nibble at the kraft pulp market, but in many paper grades it cannot be used as a substitute. The Alcell® process will find a niche in locations where its small economic size is important. Development beyond that point will depend on finding more outlets for the lignin than cellulose.

The hybrid solvent processes Organocell and ASAM are very significant in Germany where kraft mills are not welcome and emission regulations are strict. Neither technique seems capable of directly challenging kraft; nevertheless, the start-up of these processes in Germany will be followed with keen interest in North America.

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Panel 3:
Alternative and Emerging Technologies — Pulping

Question and Answer Session

■ **Norman Liebergott,** *DuPont Canada, Inc.:* First, I have a question for Bruce Fleming. That was a good speech, Bruce. In your younger years, when you were doing research with me, we looked at many oxygen pulping processes. Now there is something from Russia called the pulsating oxygen cooking process. Can you say anything about that?

■ **Bruce Fleming,** *Boise Cascade:* Pulsating cooking processes are odd. Do they put oxygen into the digester?

■ **Norman Liebergott:** Yes.

■ **Bruce Fleming:** I find it hard to imagine how the fibers can be scraped off as they're cooked and removed from the digester without interfering with the liquor flow. Perhaps Brian or the digester experts would know. I can see how you can cook chips and pass the liquor through a column of chips, but not once you start scraping off the fibers and producing pulp. Remember that the consistency in the digester, if you think of it that way, is about 20 to 25 percent. There's not much liquor and lots of wood, which is fine as long as you keep the fibers packed together in chip form. When you start to scrape them off and get pulp, how can you get the liquor through them? The answer to your question is that I don't have enough information on the Russian process to know how well it would work, and I find it hard to understand.

■ **Norman Liebergott:** Brian, you were showing how much the nonchlorine or totally chlorine-free (TFC) pulps depend on kappa number decreases in the digester, and we know what the Modified Continuous Cook (MCC) and the SuperBatch™ can do. Have you ever tried, on a commercial scale, the addition of anthraquinone to an MCC to further lower the kappa number, while yet maintaining the actual yield?

■ **Brian Greenwood,** *Kamyr, Inc.:* In studies that I have participated in, we have never done anthraquinone in MCC or any MCC digester on a commercial scale. However, the laboratory results do show that you get the same yield benefits from anthraquinone with these processes as you do from conventional processes. In addition, it looks like the effect of a polysulfide in these processes and anthraquinone would be added to bring the yield up. But it has not been done commercially.

■ **Unidentified Speaker:** I think I can answer Norm's questions. The Russians have a procedure for taking the fibers out of the digester, which, I think solves the circulation problem. As the fibers are loosened by the delignification action, they are taken out of the pressure vessel and treated elsewhere. The answer to the question about anthraquinone plus extended delignification is that it works very well. We are doing that at several locations. Now, my question is for Lars Åke. I don't think I heard you say it in your presentation, but I wanted to clarify it. Was all the data you showed laboratory data?

■ **Lars-Åke Lindström,** *Sunds Defibrator Industries, AB:* Not quite all of it. Some results were produced using mostly mill produced SuperBatch™ kraft pulps. The AOX data or effluent characteristics were produced in laboratory bleaching experiments on different types of pulps. So it is possible to get a relationship of COD, color, and BOD versus kappa number of unbleached pulp.

■ **Unidentified Speaker:** In other words, there really is a mill that's producing bleached pulp for commercial use to Kappa 15? And oxygen bleaching to Kappa six?

■ **Lars-Åke Lindström:** You are going to see that happen next year. Today, we are several developmental steps away from SuperBatch™ pulping. We have two mills today that produce oxygen-bleached, softwood kraft pulp with a Kappa level in the range of 8 to 12. That is quite a development of the process, I think. The implementation of Superbatch™ cooking will happen this year, and several mills will follow next year.

■ **Unidentified Speaker:** A number of exciting things are happening, but I think we need to be careful to draw a distinction between what is happening and what we think or hope will happen.

■ **Lars-Åke Lindström:** I agree with that.

■ **Neil McCubbin,** *N. McCubbin Consultants, Inc.:* A couple of questions for Lars Åke. You mentioned cooking softwoods down to a kappa number of about 10 with your extended cooking process. What were the effects on pulp yield when you went to this number?

■ **Lars-Åke Lindström:** Compared to conventional kraft cooking, which took a kappa number of about 30, the yield will be lower. What we have seen in comparing this process to commercial cooking is that we improve the yield at the given kappa number. That means that you can cook the pulp, the chips, to a lower kappa number without severely loosing yield.

■ **Neil McCubbin:** You talk about the integration of extended cooking with oxygen delignification and how that affects the yield. If you use the batch process and cooking, would the coverage be the same? Can you comment on how it might differ?

■ **Lars-Åke Lindström:** The results that we have achieved in mill-scale and lab trials show that it is possible to pulp the kappa number down to 10 with a yield of about 44 percent, as compared to conventional kraft cooking down to a kappa number of 30 with a yield of about 47 percent. So there is a drop in yield when you extend the delignification.

■ **Neil McCubbin:** My other question was, have you retrofitted SuperBatch™ in any other batch digester mills? Can you comment on the feasibility of that?

■ **Lars-Åke Lindström:** Well, as I said, the batch cooking process has developed over, let's say, 10 or 12 years. And in that development we have retrofitted digester plants to approximate the SuperBatch™ process, but we have not as yet retrofitted any digester plants fully.

■ **Douglas Reeve,** *Pulp and Paper Centre, University of Toronto:* Also for Lars Åke, a point of clarification. You suggest that the amount of pulp produced by oxygen delignification worldwide is 50 percent of the total kraft pulp produced. Given that the United States uses oxygen delignification for only 25 percent of its pulp and given that this figure is even lower in Canada, do you not mean that *outside* North America, the total is 50 percent. I think that 50 percent worldwide is an excessive claim.

■ **Lars-Åke Lindström:** Worldwide is approximately all the world including North America. My understanding is that oxygen delignification now exceeds 50 percent of all pulp produced. It is a controversial subject, obviously. I must say that I include also, the . . . capacity.

■ **Douglas Reeve:** What capacity?

■ **Lars-Åke Lindström:** Capacity that hasn't started up yet in the mills that have decided to install oxygen delignification.

■ **Douglas Reeve:** My question relates to your recovery of ozone filtrate and your recycling of spent gas from the ozone reactor. You showed two very neat recycles on your process flow chart. I wonder if you could advise us as to the development of those two recycles. They are exceedingly demanding technically.

■ **Lars-Åke Lindström:** That is true. In this context, I would like to mention the enormous amount of work by Union Camp. It has extensively researched the recycling of the spent ozone gas and the recycling of the ozone bleaching spent liquor. I agree with you that one has to look at the potential problems associated with operating an acid delignification process inside an alkaline fiber line. We are very positive that we can achieve the results I showed you earlier today, and we will know this for sure next month when Union Camp implements recycling at the Franklin Mill. In new developments, you can't always answer every question by running laboratory trials. You have to implement the technology in full scale to find the final answers. I think that Union Camp has set a very bold objective, namely, to find out about this.

■ **Tom McDonough:** Lars, You said that you are optimistic about the possibility of achieving what you showed us in your presentation. Does that mean you are optimistic about achieving 100 percent of the recycled ozone filtrate, or do you think there will have to be a purge in the system?

■ **Lars-Åke Lindström:** I am optimistic about recycling 100 percent of the ozone filtrate.

■ **Dick Valley,** *Michigan Pulp and Paper Corporation:* Bruce, were your cost comparisons based on the actual physical cost of producing the pulp or do they include the necessary environmental costs associated with different types of pulping? In other words, some have air emission problems, some don't.

■ **Bruce Fleming:** This is true. Let me think about this question because the answer is different for the different processes that I talked about. The Organocell figure was the total cost to build a mill, because that firm has just built one that's about to start up. Alkaline sulfite anthraquinine methanol (ASAM) plants would need some environmental controls on the recovery furnace, because ASAM uses a high sodium sulfite recovery furnace. That I did not take into account; I figured that there is going to be a higher capital cost in kraft anyway. We added 10 to 20 percent to that process because of the methanol recycle loops and the higher pressure of the digester. So, in that case, there's an additional cost for environmental control. For Soda-AQ and Alcell™, the air emission controls are insignificant. They don't apply in that case as compared to kraft.

■ **Pete Radecki,** *Michigan Technological University:* I would like to commend our foreign visitors on some of the efforts that were mentioned in regard to demonstration plants and otherwise for some of the alternate technologies. My question is primarily to Bruce. Do you have any feel for the level of research and development funding that North American companies are expending on alternate processes, or do you think that those might be misdirected funds?

■ **Bruce Fleming:** I wouldn't think that such developments would be misdirected, but I don't have any feeling for the amount of money that North Americans spend on research and development. No doubt a lot of this research is going on in Germany. The reason is that there has never been a kraft industry in Germany. The kraft process has not been permitted in western Germany since the war. So the Germans have quite a bit of softwood. They are able to pulp spruce by the sulfite process to make the totally chlorine-free sulfite pulp that they use very effectively. But their pine is exported to countries like Sweden and Austria where kraft pulping is permitted; then the pulp is returned to Germany.

So Germany has had a tremendous incentive to develop a nonkraft alkaline pulping process to deal with this pine wood. And there has been government funding for this development. That's why so much research has been done there and it is very satisfying to Germany that these processes are being watched here with great interest. They are not quite economically up to kraft yet. We don't have here the same impetus to do research in the alternative processes that the Germans do, but, of course, U.S. and Canadian companies are developing the Alcell™ process. So there is research in alternative pulping going on in North America.

■ **Pertti Visuri,** *Ahlstrom USA, Inc.:* I have a comment rather than a question to supplement Mr. Fleming's presentation. One successful way of making up for the additional capacity needed in the recovery boiler has been implemented in several of our mills. It requires a heat treatment on the black liquor to lower the viscosity. This way you can have higher percentages of dry solids going to the recovery boiler, which adds capacity and has several other advantages, including less need for waterwashing the steam pipes.

■ **Lubomir Jurasek,** *Pulp and Paper Research Institute of Canada:* I have a question for Dr. Lindström. You mentioned a modified lignin process, a sequence of ZXP. What does the X stand for? Is it xylanase, or is it a chelator?

■ **Lars-Åke Lindström:** The X stands for a chelating stage, which is necessary to remove the heavy metals.

■ **Lubomir Jurasek:** We often use X for xylanase; for the enzymatic, we use Q, at least in Canada. If you did not use enzymes, why did you use that? It seems to be beneficial, but I would place it a little earlier in the sequence.

■ **Lars-Åke Lindström:** I am sure there are various alternatives to improve pulping and bleaching technologies. I discussed only the few that I know best and have been personally involved with. And, yes, there are different ways to improve these situations.

Bleaching of Kraft Pulps — A Research Perspective

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The bleaching process for chemical pulp manufacture is undergoing a dynamic development. In a few years, molecular chlorine will be replaced almost completely by a combination of oxygen and chlorine dioxide. The standard sequence in Scandinavia for market softwood kraft pulp is O D(EPO)DD. Strict environmental demands can best be met by using chlorine dioxide, oxygen, and peroxide.

Two strong trends have appeared in the development of the bleaching process. The first is totally chlorine-free (TCF) bleaching; the second is the closed-cycle mill concept. The alternatives for TCF bleaching include hydrogen peroxide, oxygen, ozone, enzymes, reducing agents, and maybe most important, modified extended draft cooking. There is a great potential for improvements in TCF bleaching. Ozone is probably the most interesting chlorine-free bleaching chemical because of its very good bleaching effect; however, the complex radical chemistry of this particular process is not fully understood.

The closed-cycle mill concept is still far from a reality, but it is more possible now than it was a few years ago. From a broader perspective, such a mill is a fit complement to the idea of sustainable development. The kraft process has natural bleeds for many elements that enter the mill with the wood and raw water. One of the major challenges in the closed-cycle mill is the handling of manganese.

Development Until 1992

During the last two decades, considerable progress has been made in reducing the formation of adsorbable organic halogens (AOX) in the mills that manufacture bleached chemical pulp. This progress is indirectly illustrated in Figure 1, which shows the amount of chlorine consumed per ton of bleached pulp over the last 15 years in Sweden. Eighty-five percent of the Swedish production of bleached chemical pulp is kraft; 15 percent is sulfite pulp.

The big decrease in the consumption of molecular chlorine has resulted in a corresponding decrease in the formation of AOX (Swed. Forest Indus. Water Pollut. Res. Found. 1991; Hultman, 1992). From 1970 to 1986, the AOX formed in the process decreased from about 8 kg to about 4 kg per ton of pulp in Sweden. The AOX discharged per ton of pulp was reduced another 75 percent by 1991, for a total AOX decrease of about 90 percent since 1970.

The introduction of different techniques for reducing the bleaching effluent is shown in Figure 2. Starting with the "conventional" sequence CEHDED in the early 1970s, the first step was to install oxygen bleaching in a number of mills. This change is the main reason for the large decrease in chlorine consumption. A gradual replacement of chlorine by chlorine dioxide also contributed as did the fact that an increasing number of mills began to treat the effluents biologically in aerated lagoons.

The standard sequence in Sweden in 1992 for softwood kraft pulp is O D(EPO)DD; oxygen delignification, 100 percent ClO_2 in the prebleaching and reinforced alkaline stages. The main characteristics of this sequence are a low formation of AOX, no formation of polychlorinated compounds, an extremely low level of particles in the pulp, good pulp strength, and good brightness stability.

The current low level of AOX, around 0.5 kg per ton, is achieved by using this bleaching sequence. Even lower levels can be reached by combining this sequence with modified extended kraft

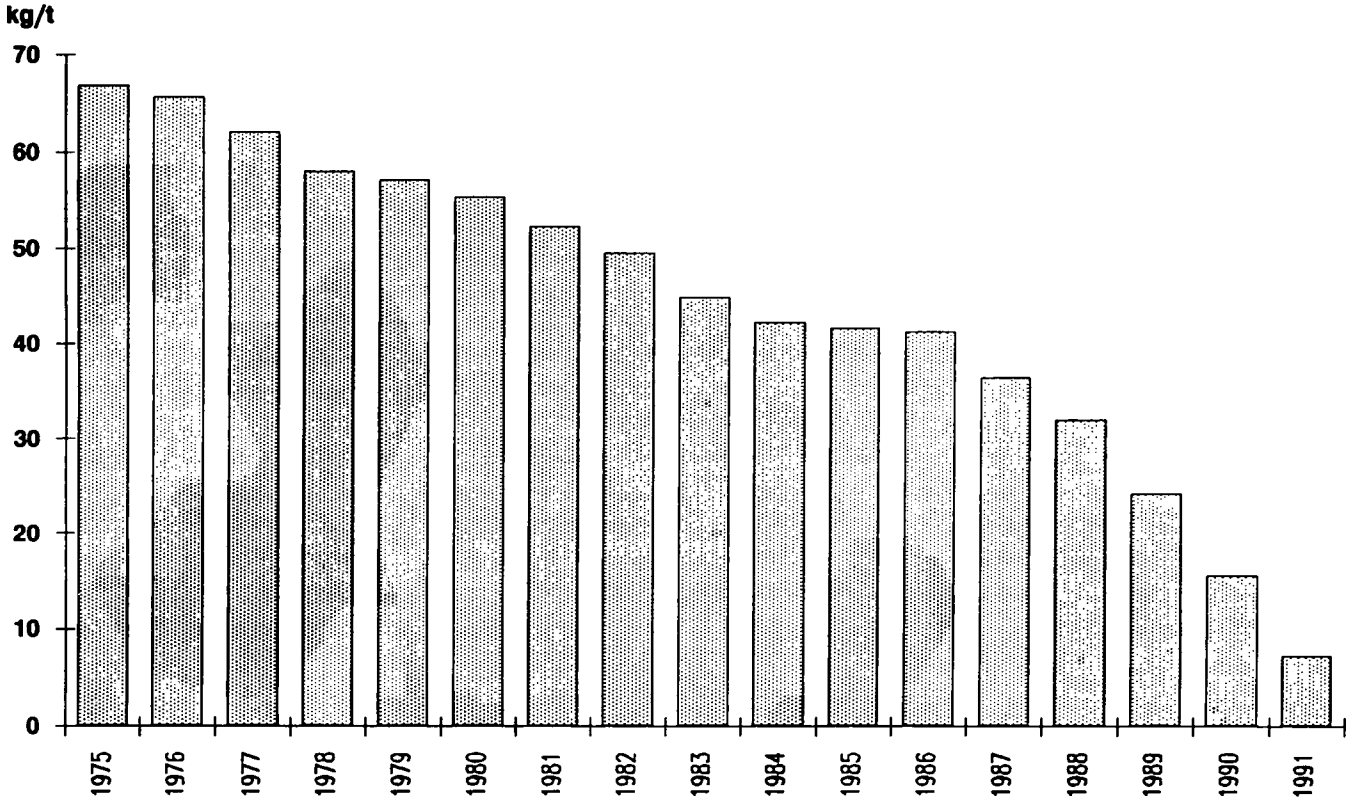


Figure 1.—Consumption of chlorine in the Swedish pulp and paper industry, 1975 to 1991.

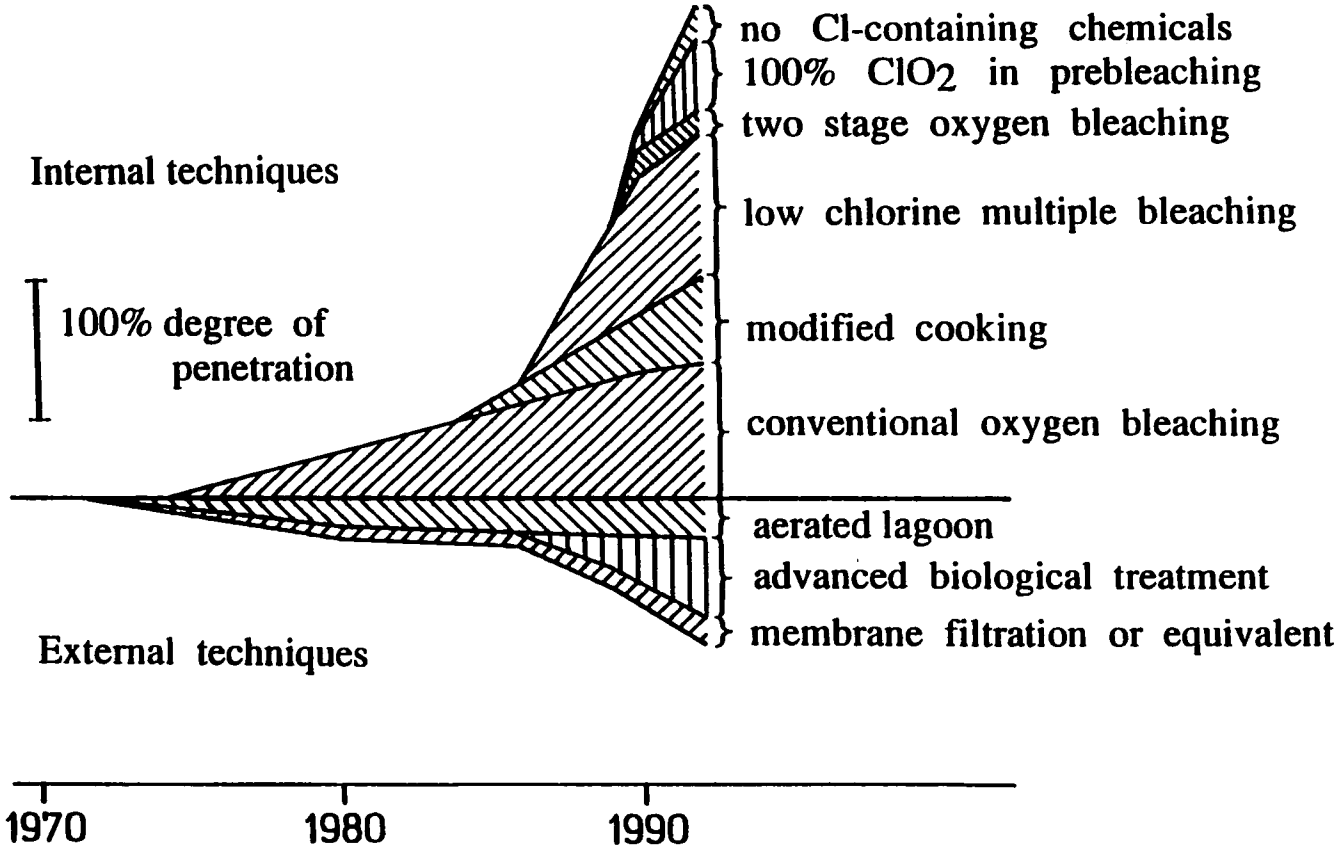


Figure 2.—Gradual introduction of different internal and external processes intended to minimize the effluent load from Swedish mills for bleached chemical pulp during the years 1970 to 1992.

cooking, external treatment, and good process control. At this low level, the AOX value has no significant environmental impact.

The impact on surrounding waters cannot be explained only by the presence of discharged or natural AOX and specific organochlorine compounds. Both Canadian (O'Connor et al. 1991) and French (Charlet, 1991) studies have shown that there is hardly any correlation at all between AOX/EOX and chronic or acute toxicity. Nonchlorinated extractives originating from wood have also recently been shown to have effects on liver enzyme activity in fish (Lehtinen, 1991).

Evidence has been found for the existence of such "natural AOX" (Grimvall et al. 1991). Ancient groundwater samples have been shown to contain organochlorines, but these tend to have low chlorine-to-carbon ratios, which makes them more easily biodegraded and gives them low toxicities. There also seems to be a "natural dehalogeneration." Thus, natural AOX is both formed and degraded by biological processes (Fleming, 1992).

Despite these data, the market continues to show a strong interest in TCF bleaching. Today about 5 percent of the bleached kraft pulp in Sweden is TCF bleached by a combination of extended kraft cooking, oxygen, hydrogen peroxide, and, occasionally, enzymes.

Potential for Different Bleaching Chemicals

Chlorine Dioxide

Chlorine dioxide (ClO_2) is the most effective chemical in a modern bleaching plant. It is selective, relatively cheap, and relatively insensitive to process disturbances.

Furthermore, the amounts of chlorinated dissolved material in the effluents are lower from a bleach plant using chlorine dioxide than from a bleach plant using a sequential chlorine/chlorine dioxide stage. The chlorinated material from a D100 stage, mainly consisting of chlorinated phenolic lignin residuals of different molecular weights, has a low degree of chlorination per aromatic residue. Primarily, monochlorination seems to occur on the lignin matrix in the pulp during the 100 percent chlorine dioxide treatment (Ljunggren, 1991). This occurs together with ring-opening reactions and the formation of acid end groups that are necessary for lignin dissolution in the first bleaching step. The dominant dissolved phenolic organochlorine compounds are thus of monochloro nature — some dichlorophenolics do exist — but hardly any tri- or higher chlorinated compounds (Histed et al. 1991).

Chlorine dioxide is also very beneficial in degrading polychlorinated phenols to less chlorinated compounds, something that we have observed in model compound studies (see Fig. 3). This behavior can also contribute to the negligible amounts of tri-, tetra-, and higher chlorinated compounds observed when bleaching with a mixture of chlorine and chlorine dioxide.

The toxicity equivalency factor, relating the chronic toxicity of an individual chlorophenol to that of pentachlorophenol, shows a drastic decrease when the chlorine gas consumption is decreased and with a decreased kappa number (see Fig. 4).

Microtox tests are valuable tools for screening toxicities (Renberg, 1992) and have been performed on 100 percent ClO_2 mill effluents after exposure to an aerated lagoon. No toxicity could be measured, which indicates no toxicity at least on marine bacteria (Dahlman, personal communication).

Effluents from pulps bleached with chlorine dioxide seem to have low chlorine-to-carbon ratios (see Table 1). It is of interest to compare this level with figures reported for Swedish chlorinated drinking water: 0.003 to 0.015 chlorines per carbon atom (Cl/C) (Annergren et al. 1990). In our studies of the isolated lignins from pulps bleached with 100 percent ClO_2 we have found even lower ratios (0.005 Cl/C) in the residual lignin in the pulp than in the dissolved high molecular lignin residues in corresponding bleaching effluents.

Table 1.—Fraction of chlorine per carbon atom (Cl/C) in the high molecular part of lignin during bleaching.

AMOUNT D IN PREBLEACHING	Cl/C IN EFFLUENT
30	0.035
50	0.025
80	0.021
100	0.011

In the future, there may be possibilities to further decrease the amount of chlorinated organics by optimizing the bleaching process parameters — for example, through the use of higher or better controlled pH levels and the addition of chemical additives.

Enzymes

Great interest exists in the use of enzymes, particularly xylanase, in bleaching. Xylanase itself does not bleach, but it does seem to improve bleachability in the later stages. The principle behind this theory is illustrated in Figure 5. The basic theory is that the enzymes "soften" the fiber structure so that the lignin is more easily attacked in later

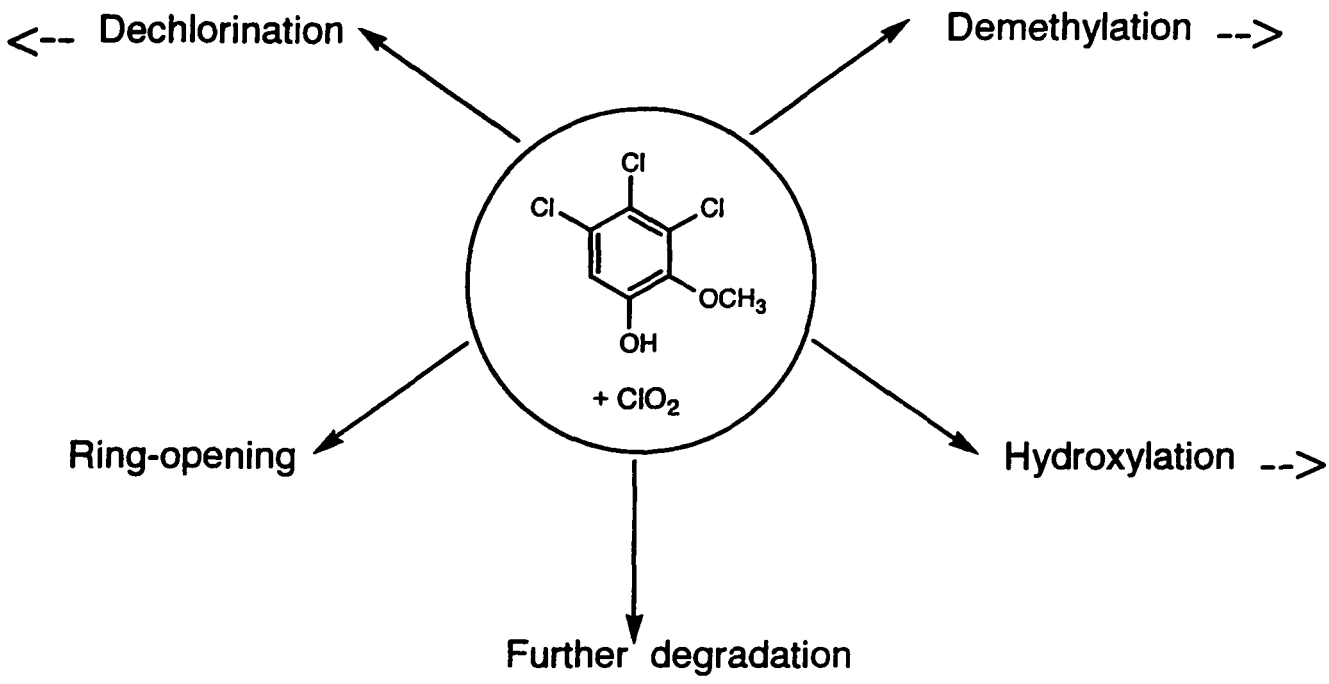


Figure 3.—Chlorine dioxide can degrade polychlorinated phenols to less hazardous compounds. —> = further degradation in the alkali stage via corresponding quinones.

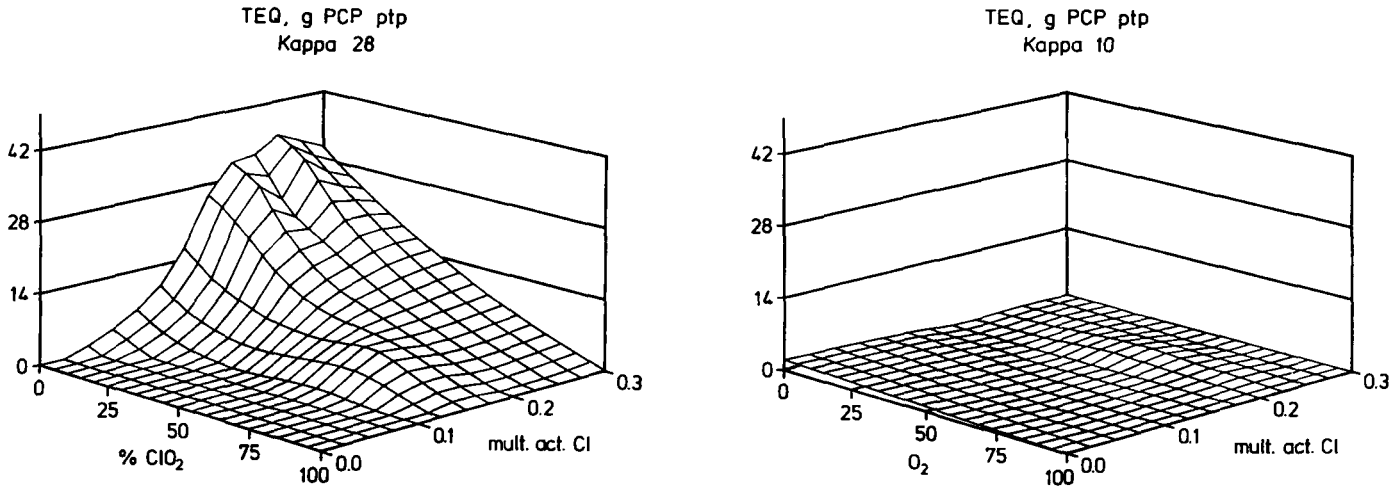


Figure 4.—Chlorinated phenolics (expressed as toxic equivalents of pentachlorophenol (PCP) in g/t of pulp) are dramatically decreased by modifying the bleaching process or by decreasing the Kappa number.

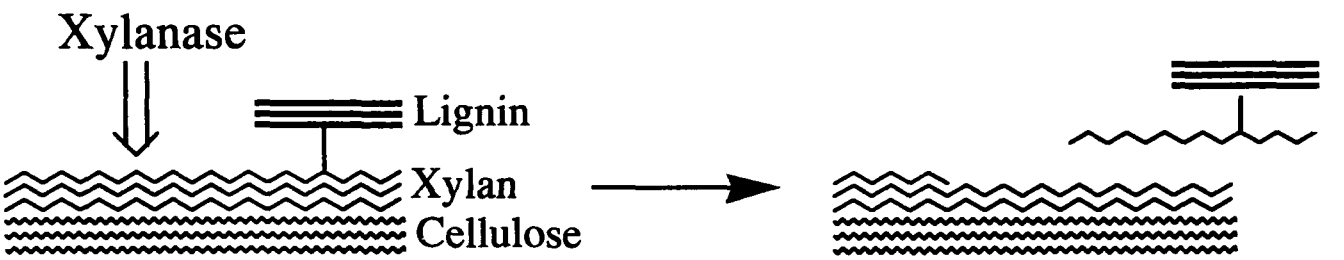
bleaching stages. The benefit of enzymes, however, seems to decrease with lower kappa numbers and to be marginal in modern systems of TCF bleaching. Moreover, the yield loss that accompanies the use of enzymes will increase the wood costs and increase the load of chemical oxygen demand (COD).

Oxygen

Oxygen is an environmentally friendly chemical but unfortunately the delignification rate in oxygen bleaching is slow and has to be interrupted at about 50 percent of delignification because of too severe loss of carbohydrates. The reason for this inefficient delignification is the nearly nonexistent reactivity of the nonphenolic structures in lignin. Oxygen reacts only with free phenolic groups in the residual lignin in kraft pulps (see Fig. 6).

The main benefit of using oxygen in the process is after the cooking or bleaching steps in which phenolic groups have been liberated, that is, after kraft pulping and in the alkaline extraction stages. However, the reactivity of the phenolic groups in certain lignin structures, for example, in biphenyl

Indirect release of lignin-carbohydrate linked lignin



Uncovering of lignin

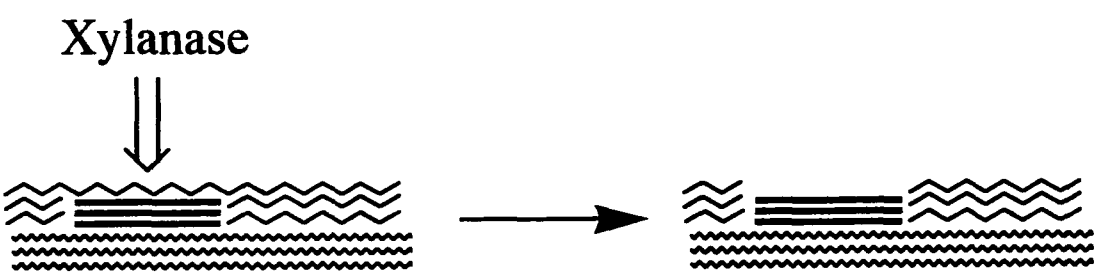


Figure 5.—Hypothesis for the effect of enzymes on bleachability.

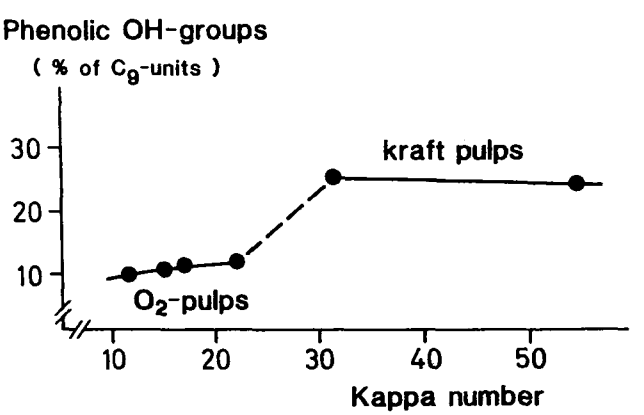


Figure 6.—Phenolic hydroxyl groups in residual lignins. During oxygen bleaching the phenolic groups in residual lignin decrease rapidly at first, indicating that oxygen reacts quickly with these groups.

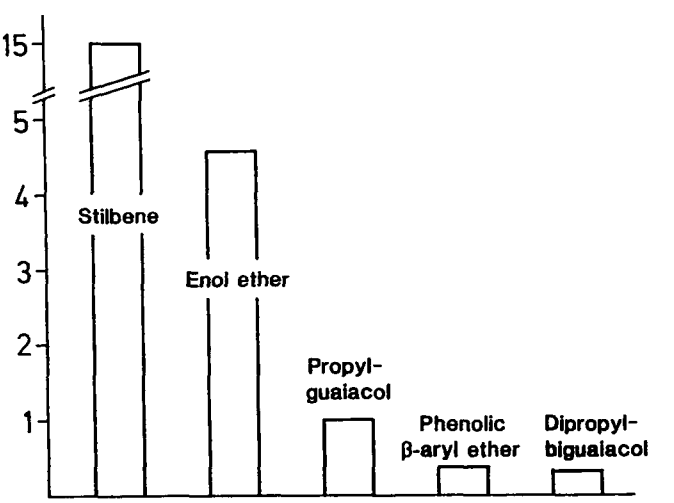


Figure 7.—Relative rates during oxygen bleaching conditions of some models for phenolic structures present in residual lignin.

or cross-linked lignin structures, is very low (Ljunggren et al. 1991).

Figure 7 shows that the relative rates become very different for free phenolic (guaiacyl) and biphenolic cross-linked structures during oxygen bleaching.

The cross-linked structures are relatively stable and are partly accumulated in the oxygenated residual lignin. The efficiency of oxygen in delignification would therefore increase if these biphenolic groups could be made reactive, and would be even better if methods could be found to cleave nonphenolic structures during oxygen delignification.

Hydrogen Peroxide

Hydrogen peroxide has gained more interest and attention as a delignifying agent in the various steps of a bleaching process, even for alkaline produced chemical pulps. Stabilized alkaline hydrogen peroxide in the absence of metal ions is essentially a brightening and not a delignifying agent. Such brightening is a result of the oxidation of the chromophores in lignin by the perhydroxyl ion HOO^-(dissociated peroxide). However, neither this ion nor hydrogen peroxide itself is able to react with or oxidize nonphenolic or phenolic structures and delignify the pulp without appreciable yield losses. For this reason hydrogen peroxide has been called a lignin-preserving agent. To use hydrogen peroxide as a delignifying agent, it must be partially decomposed. Peroxide decomposition is necessary for phenolic structures of the type present in residual lignin to be attacked by hydrogen peroxide (Agnemo and Gellerstedt, 1979; Smith and McDonough, 1985; McDonough et al. 1987). The decomposition involves formation of radical species that can attack phenolic lignin units:

$$H_2O_2 + HOO^{-\,M+} \rightarrow HO\cdot + O_2^{-\cdot} + H2O$$

The decomposition occurs spontaneously in the presence of transition metal ions to different degrees depending on the kind of metal ion. The relationship between the catalysis of H_2O_2 decomposition and the extent of phenol association of a cross-linked lignin structure model has been studied in presence of metal ions such as copper, iron, manganese, and iron cyanide (Smith and McDonough, 1985). The ratio of the rates of H_2O_2 decomposition and lignin model oxidation increased in the presence of iron and manganese. This ratio suggests that these metals consume H_2O_2 through decomposition to oxygen.

However, the results of copper and iron cyanide in this example indicate that not all metal species may be considered detrimental. Thus, it may be possible to increase the extent and rate of delignification for a given hydrogen peroxide charge by controlling the levels and types of metal ion species in the pulp. It is apparent that the decomposition of hydrogen peroxide must be controlled to some desirable level. It may, for instance, be necessary to limit the effect of the decomposition catalysts by adding an inhibitor. Such inhibitors are complexing agents with metal ions, for example, ethylenediaminetetraacetric acid (EDTA) or silicate (McDonough et al. 1987). An interesting metal catalyst is manganese; it probably contributes to decomposition of peroxide and is directly involved in delignification via increased phenoxy radical formation from phenolic lignin units. Thus, by finding methods to direct manganese ions to suitable areas in the cell wall matrix, for example, to its lignin rich parts, it should be possible to enhance the efficiency of hydrogen peroxide (see Fig. 8) (Vannerberg, 1992).

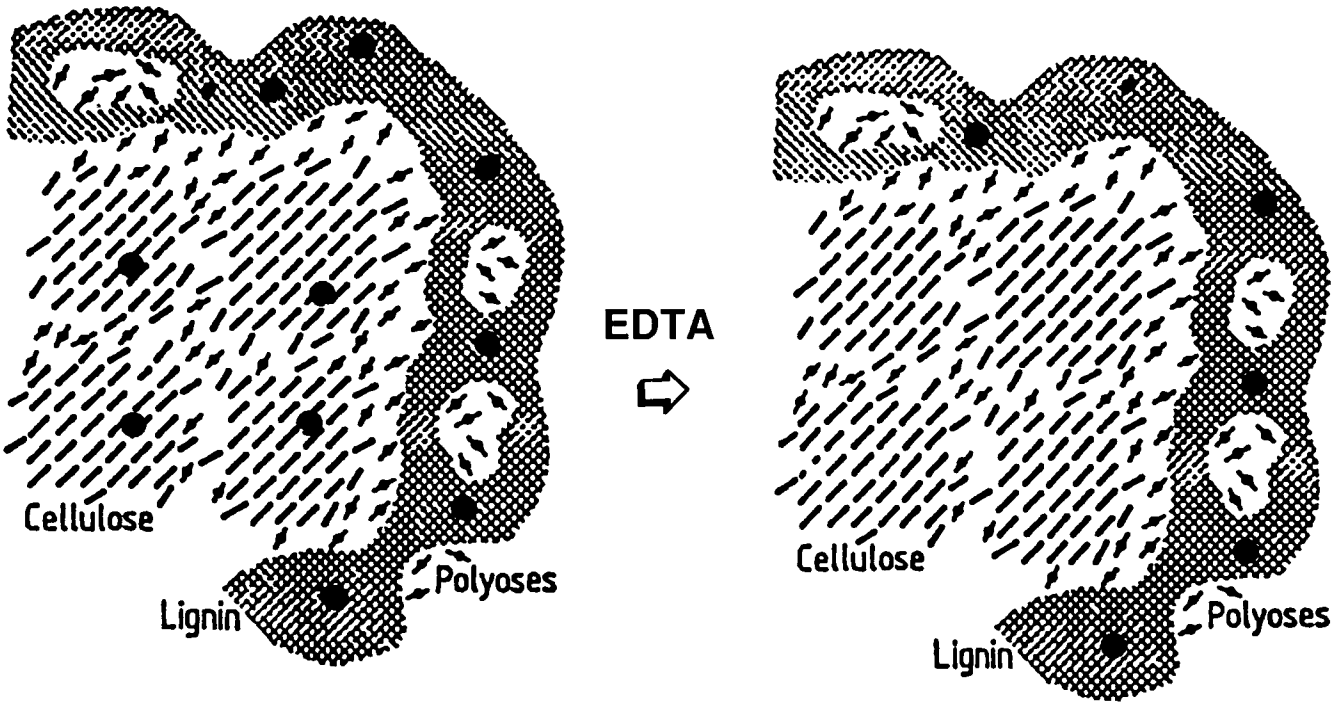


Figure 8.—The selective removal of manganese. Catalytic metal ions such as manganese are in the fiber wall. Treatment with the complexing agency EDTA removes the catalyst from the cellulose parts so that the remainder is left associated with the lignin (Vannerberg, 1992).

Ozone

Ozone is a third very promising nonchlorine bleaching chemical with big potential as a delignifying and bleaching agent (Figs. 9 and 10). Ozone has a great lignin-degrading ability, similar to that of chlorine dioxide, but unfortunately ozone also degrades cellulose and results in bad selectivity (Liebergott et al. 1992). In contrast to oxygen and peroxide, ozone reacts with both phenolic and nonphenolic lignin structures. Thus, ring-opening reactions of the aromatic ring occur and form acidic groups that facilitate the lignin dissolution (Patt et al. 1991). Cleavage of nonphenolic structures gives a comprehensive degradation of the lignin matrix (Eriksson and Gierer, 1985). These direct reactions take place quickly and extensively in an acid environment. But ozone, like chlorine dioxide, is not very stable in an alkaline solution; it decomposes and becomes inactive. However, ozone also reacts indirectly with the carbohydrates in the pulp causing a poor selectivity. These indirect reactions, caused by water, are radical in nature. Thus, in developing the ozone bleaching process, research should be directed toward processes in little or no water, and to the suppression of the radical formation.

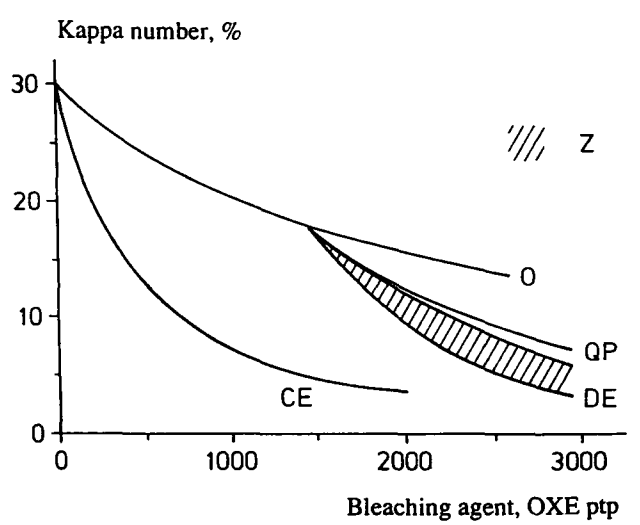


Figure 9.—Kappa number after prebleaching of a softwood kraft pulp with different bleaching chemicals. See Table 2 for conversion to OXE. The range for ozone depends on whether four or six electrons are used in ozone bleaching.

Hydroxyl Radicals

Cellulose and hemicellulose degradation is initiated by radicals abstracting hydrogen atoms from the sugar unit and thereby creating a β-elimination reaction. This leads to random cleavages in the carbohydrate chain. The main radical causing this damage to the cellulose is the hydroxyl radical

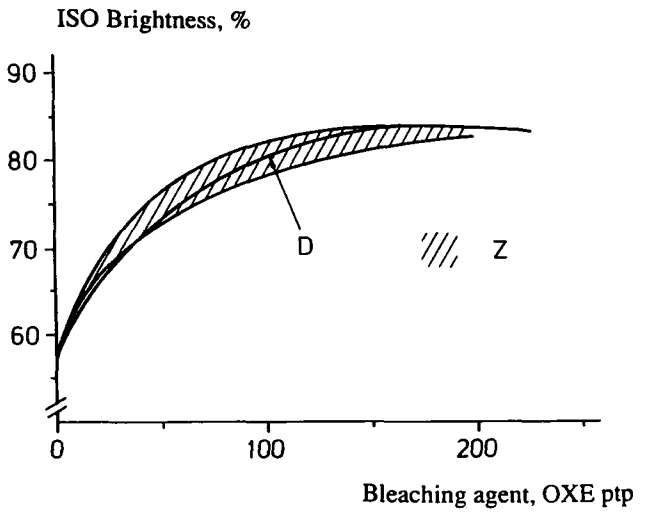


Figure 10.—Brightness response of ClO_2 and Z on O(C+D)(E+D) prebleached softwood kraft pulp. See Table 2 for conversion to OXE. The range for ozone depends on whether four or six electrons are used in ozone bleaching.

HO·. It is also extensively reactive with lignin, causing both degrading reactions (during peroxide decomposition) and hydroxylation reactions (to a lesser degree). The latter reaction makes the lignin more hydrophilic and easier to dissolve (Terashima and Tatsumi, 1985). Its reactions are very unselective and must be controlled by radical scavengers. Such scavengers can be solvents (Brolin et al. 1991), organic complexes, phenols or even lignin itself (Jacobson et al. 1991). Even chlorine dioxide is a radical scavenger, which explains the good selectivity of chlorine dioxide during bleaching.

In general all these chlorine-free chemicals — oxygen, peroxide, and ozone — generate hydroxyl radicals and other destructive radicals for the cellulose, which creates selectivity problems during delignification with these chemicals. Development of the proper process conditions and the use of additives is necessary to achieve a good pulping process.

Oxidation Equivalents, OXE

Old bleaching sequences like CEHDED and CEDED, which only use oxidative chemicals containing chlorine, can be adequately described by active chlorine or available equivalent chlorine. Modern sequences that use chlorine dioxide, oxygen, and hydrogen peroxide use a lot of oxidation power that is not reflected in the consumption of active chlorine.

One solution to this dilemma is the concept of oxidation equivalents, OXE (Grundelius, 1991). OXE is defined as follows: 1 OXE = the amount of a substance that consumes 1 mole of electrons when the substance is reduced.

All oxidative bleaching chemicals can easily be converted to OXE according to Table 2. All chemicals here are assumed to be reduce to Cl^- or H_2O. Between four and six of the six electrons available seem to be used for bleaching reactions in ozone bleaching. The number depends on whether the reduction of ozone stops at intermediate peroxides (hydrogen peroxides and organic peroxides). In this case, only four electrons are used. If these peroxides can react with lignin at this low temperature and pH, all six electrons can theoretically be used. In the tables and figures that follow, it has been assumed that ozone uses all six electrons.

Table 2.—Relationship between molecular weight and oxidative equivalents for different bleaching chemicals.

	Mw	E^-/ MOLE	REDUCTION TO	g PER MOLE E^-	OXE/ KG
Cl_2	70.914	2	Cl^-	35.46	28.20
ClO_2	67.457	5	Cl^-	13.49*	74.12**
NaClO	74.448	2	Cl^-	37.22*	26.86**
O_2	32.000	4	H_2O	8.00	125.00
H_2O_2	34.018	2	H_2O	17.01	58.79
O_3	48.000	6	H_2O	8.00	125.00
(O_3	48.000	4	Peroxides/ O_2/H_2O	12.00	83.33)

*35.46 g active Cl mole e–
**28.20 OXE/kg active Cl

Pulp Properties

Pulp properties can be negatively affected in cooking and bleaching. If these operations are not run properly, difficulties in reaching high brightness, loss of pulp strength, loss of beatability, and deteriorated cleanliness may occur.

Brightness

Traditionally the brightness of bleached chemical market pulp has been above 88 percent ISO to guarantee a high degree of cleanliness of bark and shives. This rating also improves brightness stability, which is important for high quality printing and writing papers. High brightness is easily reached with sequences like CEHDED, O(C+D)(EO)DED, and O D(EPO)DD where there is a relationship between the kappa number and the brightness (see Fig. 11) characterized by a limited increase in brightness down to kappa numbers 5-10. Below this level, a steep increase in brightness occurs with decreasing kappa numbers. This increase in brightness at lower kappa numbers is much greater for hydrogen peroxide and ozone. Ozone and peroxide are to some extent lignin-preserving bleaching agents. At a certain brightness, the lignin content is higher for these pulps. Studies of brightness reversion on ozone and peroxide bleached pulps can therefore be of interest.

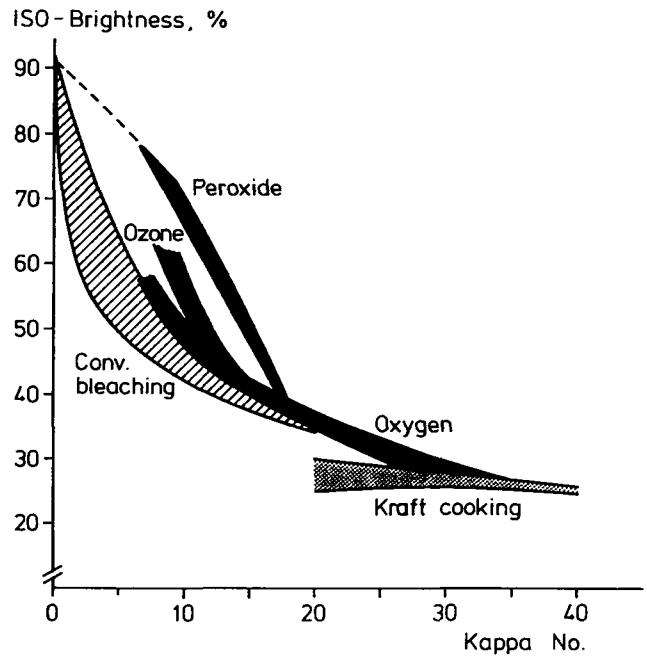


Figure 11.—Principal relationship between brightness and Kappa number of softwood kraft pulps.

Table 3 shows the approximate brightness levels that have been reached with TCF-bleaching. The development has been very rapid. A few years ago it was deemed impossible to achieve full brightness with TCF-bleaching while maintaining a good pulp quality. Today it has been shown to be possible to produce a pulp in the laboratory with full brightness using TCF-bleaching while maintaining a surprisingly high pulp quality. One promising bleaching sequence is OQ(EPO)Z(EP), shown in Table 3, which consumes considerable amounts of hydrogen peroxide in addition to some ozone. Unfortunately the cost is extremely high, especially if the level of transition metals like manganese is uncontrolled.

Table 3.—Approximate brightness values obtained for softwood kraft pulp for different TCF sequences with an acceptable strength potential. Q = chelating agent.

PROCESS SCHEME			ISO BRIGHTNESS (%) MILL	LAB
Conv. kraft	—	Q (EP)	60	
Conv. kraft	O_2	Q (EPO)	75	75
Mod. kraft	O_2	Q (EPO)	80	80
Mod. kraft	O_2	Q (EPO) Z	—	85
Mod. kraft	O_2	Q (EPO) Z (EP)	—	88–90

Pulp Strength and Beatability

All internal process measures previously discussed can cause carbohydrate degradation if they are car-

ried beyond a critical point. Two types of carbohydrate degradation cause poor pulp quality: damages to cellulosic chains cause loss of pulp strength, and hemicellulose loss makes the pulp harder to beat.

Loss of pulp strength occurs if the delignification is pushed too far in kraft cooking and oxygen bleaching. Loss of hemicellulose and the resulting loss of beatability can occur in the kraft cook and in oxygen bleaching if the delignification is carried too far. In short, too much reduction in kappa numbers can be detrimental to both beatability and loss of pulp strength.

Loss of pulp strength can also occur in the bleach plant. The risk for this increases with increased use of less selective chemicals like oxygen, peroxide, and ozone. Modern sequences with 100 percent ClO_2-substitution require more intensive conditions in the E1- and final D-stages. This also increases the risk for loss of pulp strength. The general rule is that the more oxidation power used as oxidation equivalents, the higher the risk for loss of pulp strength.

One way of comparing different sequences is on the basis of their consumption of oxidation power expressed as oxidation equivalents, OXE, as discussed in the previous section. Table 4 shows different commercial sequences with respect to their OXE. The conventional CEHDED-sequence has a very low OXE consumption. The introduction of oxygen bleaching and oxidative extraction increases the OXE-demand significantly. The latest development, with no molecular chlorine, follows this trend.

In Table 5, four sequences under development are shown. The sequence with the hydrogen peroxide stage prior to final bleaching with DPD increases the OXE-demand. However, the system is not yet fully developed.

Ozone is a very efficient bleaching agent. It is about as efficient as chlorine dioxide (see Fig. 9). In the second and third sequences in Table 5, using about 6 kg ozone per ton of pulp has decreased the use of chlorine dioxide down to 26 and 16 kg of Cl per ton of pulp respectively. An O D (EOP) DD sequence usually needs more than 50 kg of Cl per ton of pulp at a kappa number about 15. The high OXE demand in the peroxide-ozone sequence results from the large use of hydrogen peroxide, about 30 kg per ton of pulp. The peroxide demand is likely to decrease with further development. Unfortunately, ozone is also efficient in degrading carbohydrates. At present, extensive use of ozone is not possible with retention of market pulp strength. In limited amounts ozone can be regarded as a very interesting bleaching chemical provided that the high investment cost for the ozone generator can be accepted.

Cleanliness

Figure 12 (Annergren, 1990) summarizes the effect on pulp cleanliness of some internal process measures. The net effect of the sum of lower kappa number, decreased multiple, and increased share of ClO_2 is that cleanliness will be improved, making it possible to lower the brightness target somewhat. A modern sequence like O D(EPO)DD thus gives a very clean pulp.

But ozone is a very inefficient agent for bleaching shives and bark particles because the reaction is very fast and therefore the ozone is not given time to diffuse into particles. A limited use of peroxide is

Table 4.—Bleaching chemical consumption expressed as OXE (see Table 2) for industrial softwood kraft bleaching sequences. This comparison is made at an ISO brightness 90 percent.

SEQUENCE	KAPPA NUMBER	CONSUMED OXE, ptp O_2 INCLUDED	CONSUMED OXE, ptp AFTER O_2	OXE/KAPPA AFTER O_2
CEHDED	32	2,500	2,500	78
O(C85+D15)(EO)DED	20	3,900	1,500	75
O(D70C30)(EPO)D(E+P)D	16	3,900	1,500	94
OD(EPO)DD	16	4,100	2,100	110
OD(EPO)DD	10	3,300	1,300	130

Table 5.—Bleaching chemical consumption expressed as oxidation equivalents, OXE, for softwood kraft bleaching sequences under development. The comparison is made at an ISO brightness 90 percent. Q = EDTA or DTPA; Z = ozone.

SEQUENCE	KAPPA NUMBER AFTER O_2	CONSUMED OXE, ptp O_2 INCLUDED	CONSUMED OXE, ptp AFTER O_2	OXE/KAPPA AFTER O_2
OQPD(E+P)D	16	4,400	2,400	150
O(DZ)(EPO)DD	14	4,360	2,360	175
O Z(EPO)DD	16	3,690	1,690	109
OQPZP	10	4,390	2,390	239

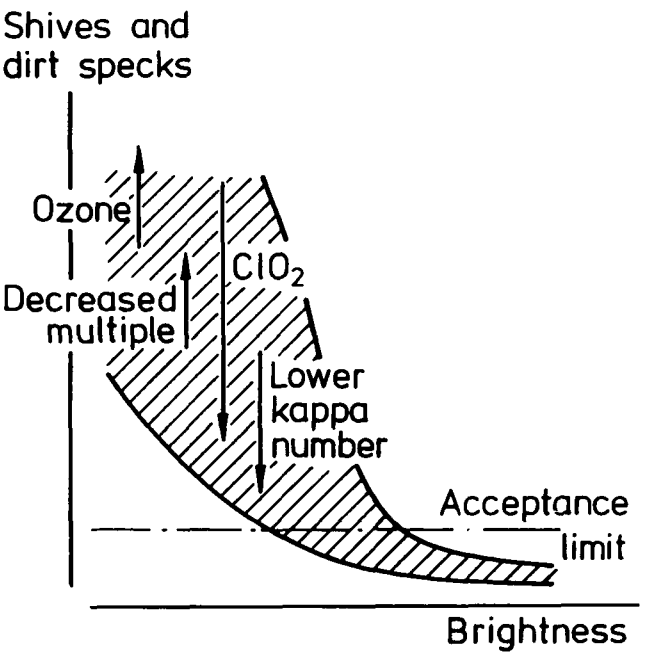


Figure 12.—Typical development in shives and dirt specks with increasing brightness. The shaded area shows a normal range of variation. The length of the arrows indicate the relative importance of the variables.

also negative for bleaching shives and bark. However, bleaching with a large amount of hydrogen peroxide characterized by a high concentration and a long retention time, efficiently removes the particles.

Bleaching in the Closed-cycle Pulp Mill

A completely closed pulp mill is not possible because everthing — the pulp fibers (the product), wood water, chlorine, silicon, phosphorus, aluminum, nitrogen, potassium, and the transition metals that enter with the wood and the raw water — has to leave the system. The kraft process, however, has a number of built-in methods by which different elements can be eliminated in a controlled way. Overall, the pulp and paper industry is amenable to the idea of sustainable development (see Fig. 13). The only input is solar energy and the output is energy to communities and industry. Everything else is part of closed loops such as recycled fibers, energy from worn out recycled fibers, ash with minerals and nutrients that are beneficial to the forest as alkali and trace elements, and the formation of CO_2 is in balance with the uptake in the forest.

This is oversimplified but it is clear that the prerequisites for sustainable development are here.

A diagram of a pulp mill in a "natural cycle" is given in Figure 14.

The cornerstone in the fiber line in a "closed-cycle" pulp mill is extended modified cooking and oxygen bleaching in one or two stages. This bleaching can be TCF, or it may use a limited amount of ClO. The TCF bleaching is based on ozone and peroxide probably combined with one or two reducing stages. There is no principal problem to handle a small amount of ClO_2 in a "closed cycle" mill provided the total input of chloride ions is below 3 to 4 kg of chloride per ton of pulp. It must be pointed out that the TCF alternative also requires a controlled bleed of chloride ions because of their presence in wood and in raw water. The acid filtrate, which contains transition metals, calcium, and phosphorus, can be bled out from the lime cycle. The alkaline filtrate can be used as washwater.

The TCF bleaching may oxidize a small amount of Cl^- to Cl_2, which could cause a limited chlorination. This chlorination can be regarded as "natural" and compared to natural chlorination that is enzyme-induced (Grimvall et al. 1991). The level of organically bound chlorine in the pulp will probably be similar to that of a modern bleaching sequence with a limited amount of ClO_2.

Conclusion

The environmental impact from chlorinated organics is greatly reduced by the use of sequences like OD(EPO)DD. In the future, it may be possible to reduce the use of chlorine dioxide to a level below the acceptable chloride input to the recovery cycle without problem. It may also be possible to continue lowering the formation of AOX.

Bleaching without chlorine-based chemicals (TCF bleaching) is developing dynamically. The main problems are its high cost and potential strength loss if the bleaching is carried to excessive brightness. Today, softwood kraft pulp can be bleached to an ISO-brightness of 80-plus, and the potential for further development seems to be great. Proper handling of metals in pulp processing is a key factor.

The use of oxidation equivalents (OXE) for quantifying the use of bleaching chemicals is recommended in modern sequences because it increases the understanding of the bleaching sequence. The best strength potential is normally reached when the use of OXE is low.

The future closed-cycle kraft pulp mill fits well with the idea of sustainable development. The bleaching chemicals in such a system might be oxygen, peroxide, and ozone. Chlorine dioxide may be needed for high brightness and good pulp strength.

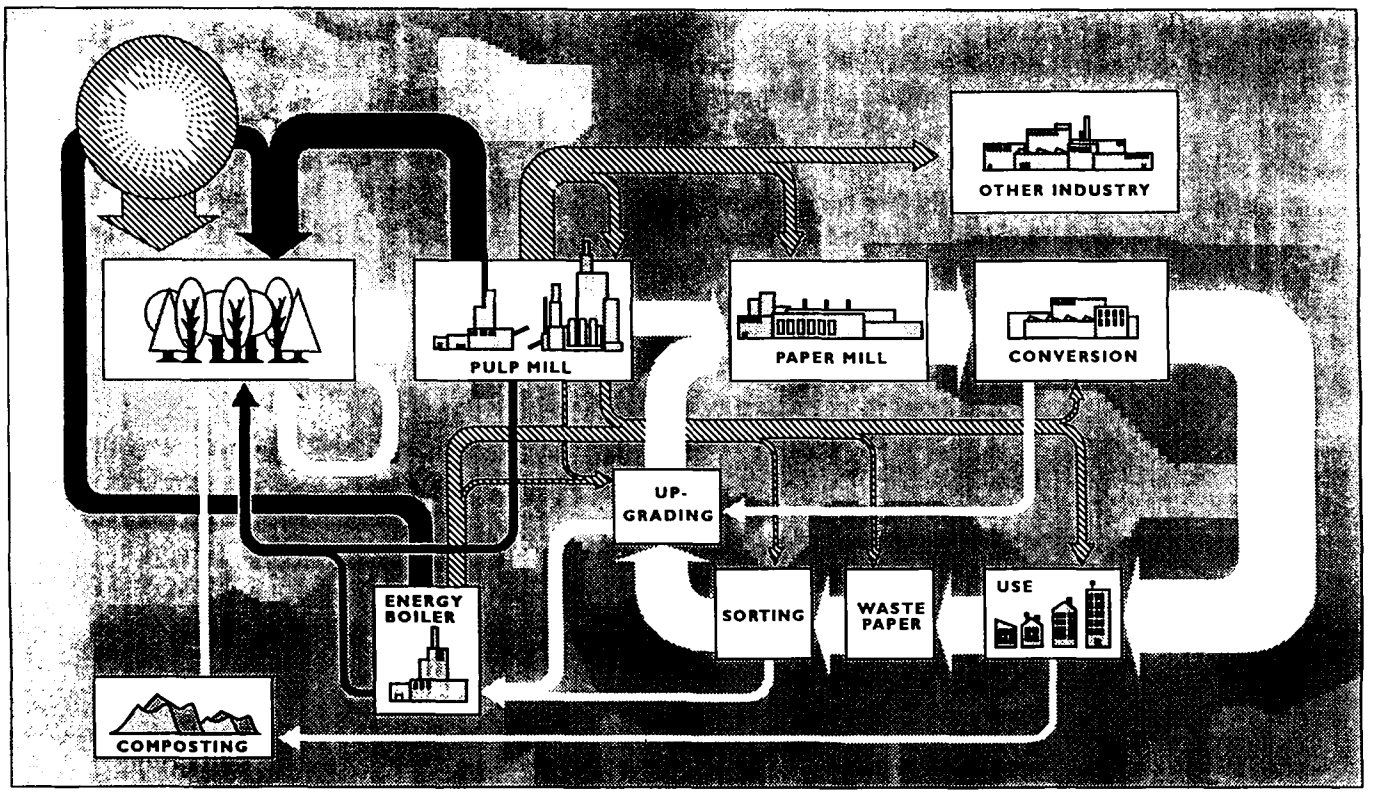


Figure 13.—Diagram of pulp and paper from a LCA perspective in sustainable development. LCA = life cycle analysis; white arrows = organic substance; black arrows = inorganic substance; shaded arrows = energy

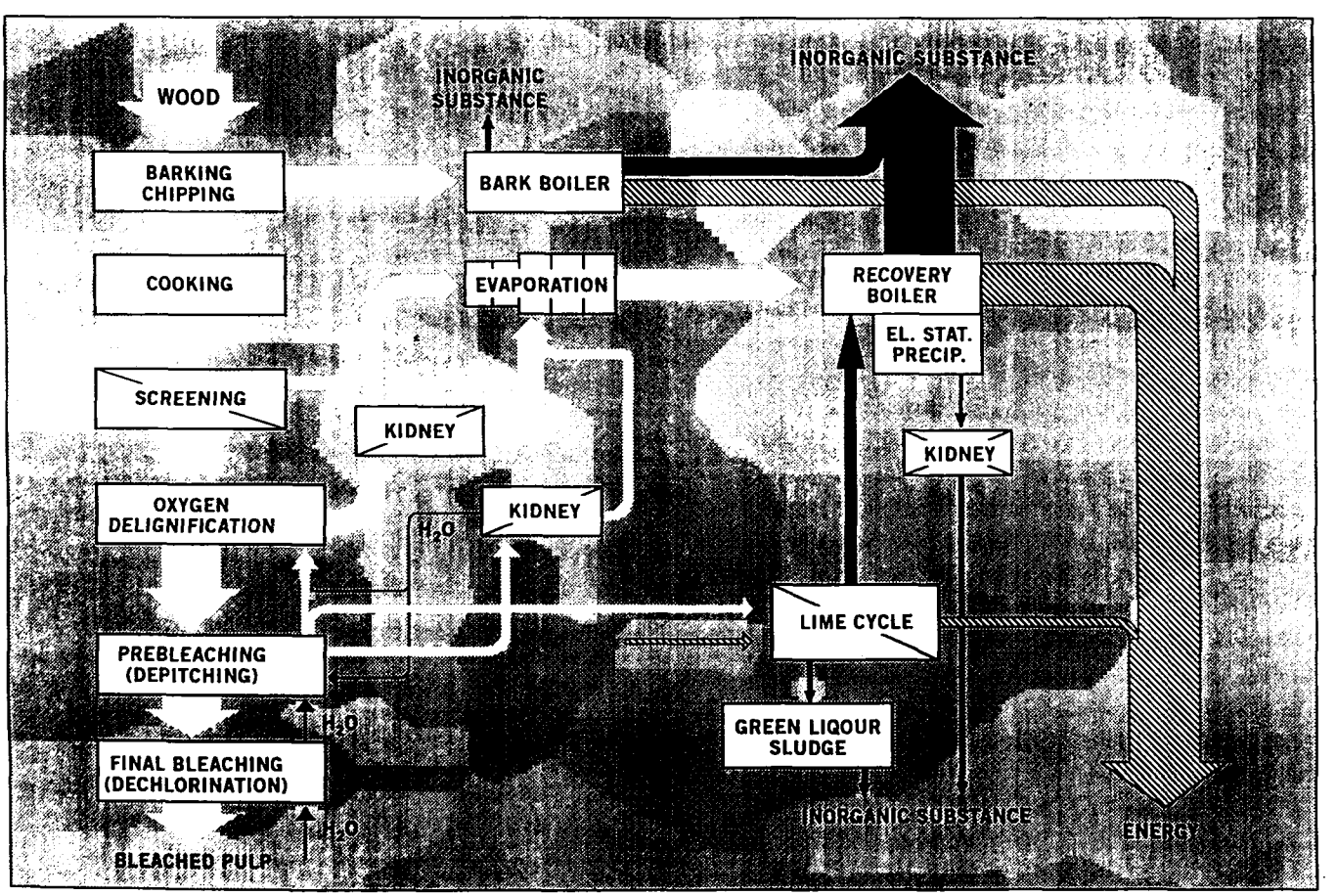


Figure 14.—Pulp mill emissions are allowed if compatible with sustainable development. The kidneys of the pulp mill are located so that the substance concentrations do not accumulate to critical levels. White arrows = organic substance; black arrows = inorganic substance; shaded arrows: energy

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The Emerging Technology of Chlorine Dioxide Delignification

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Chlorine dioxide delignification, or 100 percent substitution of chlorine dioxide for chlorine, is an emerging industrial technology. Chlorine dioxide can be used as the sole oxidant for bleaching kraft pulp to full brightness with excellent pulp strength and cleanliness. Chlorine dioxide is an extremely effective bleaching agent and should not be casually abandoned in favor of nonchlorine, or totally chlorine-free bleaching.

Chlorine dioxide has traditionally been used in latter bleaching stages, that is, for chlorine dioxide brightening, during which the pulp is retained in large towers for many hours at medium consistency (12 percent fiber in aqueous suspension). The emerging technology, chlorine dioxide delignification, uses chlorine dioxide as a complete substitute for chlorine in the first stage of bleaching.

Chlorine dioxide substitution for chlorine was first described in the 1960s, but was not immediately accepted because of its high operating cost and because substantial amounts of acid were produced in chlorine dioxide generators. In a 1985 survey, only eight North American mills were using substantial substitution and none was using 100 percent substitution. However, in a recent survey of Canadian mills, it is evident that substantial substitution has become standard operating procedure. Chlorine dioxide delignification, or complete substitution, has also recently emerged in some Canadian mills.

Chlorine dioxide delignification is completely compatible with other emerging technologies, such as extended delignification in kraft digesters, oxygen delignification, lignin leaching of unbleached pulp, enzyme treatment, and ozone bleaching. Each of these techniques decreases the lignin content of pulp before it reaches the chlorine dioxide delignification stage. Chlorine dioxide delignification is also compatible with aggressive alkaline extraction using oxygen or hydrogen peroxide. Indeed, when these treatments are aggressive enough to threaten the pulp's cellulose strength, the gentle but effective treatment of chlorine dioxide is necessary to produce pulp of good quality.

The development of on-site generator technology to produce chlorine dioxide at an acceptable price with acceptable by-products is vital to the success of chlorine dioxide delignification. All generators are based on reduction of sodium chlorate in strong acid solution. The R3/SVP™ technology, dominant in the 1970s and 1980s, produced significant chlorine by-product with the chlorine dioxide solution. But chlorine formation is virtually eliminated by switching to methanol as the reducing agent. This technology, called the R8/SVP-Lite™ technology, emerged in the late 1980s and now operates in many mills.

The other by-product from chlorine dioxide generators — a form of sodium and sulfate ions — must also be managed. The sodium sesquisulfate [$Na_3H(SO_4)2$] formed in R8/SVP-Lite™ generators is strongly acidic and usually in excess of pulp mill sodium and sulfur makeup requirements. A new process to recover sulfuric acid from the sesquisulfate, the R10™ process, has now been installed in several mills. The sodium sulfate that remains can be recovered through an electrochemical conversion of the sodium sulfate into sodium hydroxide and sulfuric acid.

In the R9™ process, electrochemical conversion is linked to the R8 generator, chlorine dioxide and sodium hydroxide are produced, and there are no by-products. Chlorine dioxide generation directly from chloric acid, another process under development, would also completely eliminate by-products.

Industrial Application of Chlorine Dioxide Delignification

A recent survey of 39 Canadian mills that produce bleached kraft pulp (34 mills were represented) provides a clear picture of the rapid emergence of chlorine dioxide delignification in Canada (Pryke et al. 1992). In 1991, 5.4 million metric tons of softwood and 1.5 million metric tons of hardwood pulp were produced using substantial substitution (25 to 75 percent), and a total of 1.3 million metric tons of softwood pulp was produced using 100 percent substitution. Total production in Canada in 1991 was 9.4 million metric tons; 87 percent was produced by substantial or 100 percent substitution — an extremely rapid rate of adoption of this practice (see Fig. 1).

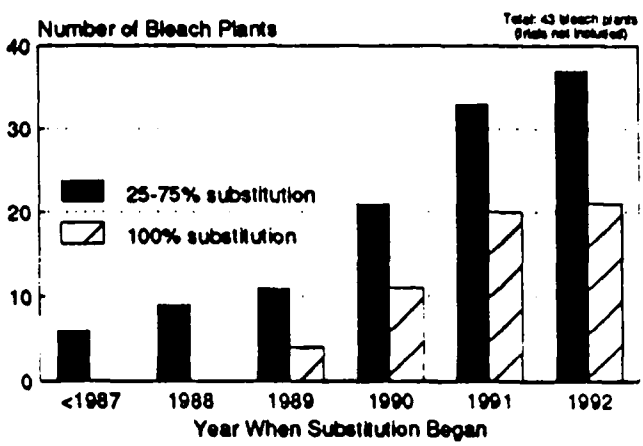

Figure 1.—Chlorine dioxide substitution practice.

Twenty bleach plants have had commercial runs of 100 percent substitution and another 11 have run trials. According to the survey, the main motivation for substantial substitution is to decrease dioxins, furans, and other organochlorines in pulp mill effluent. The principal source of market pressure is in Western Europe; there does not appear to be much pressure in North America.

The survey also requested information on advantages and disadvantages. The advantages of 100 percent substitution were many (see Fig. 2). Many mills attained expected benefits of diminished dioxins and furans. Many mills reported nondetectable concentrations were achieved by substantial substitution and by 100 percent substitution. The expected decreases in adsorbable organic halogens (AOX) and color in effluent were confirmed. A few bleach plants reported reductions in effluent chemical oxygen demand (COD), acute toxicity, and sublethal toxicity. Pulp quality was enhanced in many mills. Viscosity, strength, shive/dirt removal, pitch removal, and brightness reversion were up and sodium hydroxide consumption was down.

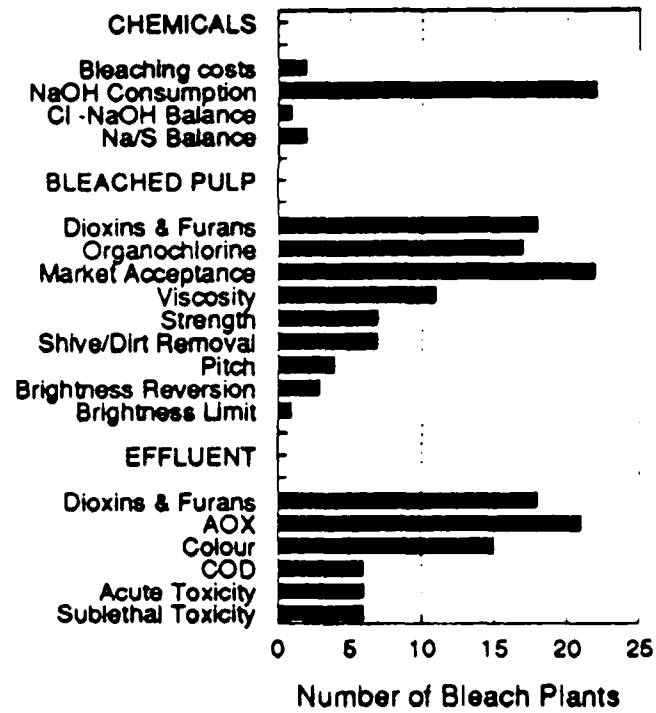

Figure 2.—Advantages of 100 percent substitution.

Cost was the main disadvantage reported for 100 percent substitution (see Fig. 3). Two bleach plants reported decreased costs, while 24 bleach plants reported increased costs. Reported increases ranged from Can$9 to Can$15 per metric ton of pulp. Many mills found the imbalance in purchased sodium hydroxide and chlorine to be a disadvantage. Another disadvantage of increased chlorine dioxide substitution is the production of more sodium sulfate by-product than is required for pulping chemical makeup. Many mills reported a lower brightness limit when 100 percent substitution was used. To increase final brightness, some mills used hydrogen peroxide to supplement caustic extraction stages.

The advantages and disadvantages of substantial substitution (25 to 75 percent) were similar with several notable exceptions. Brightness limit was not a major problem. In some cases, the cost of implementing substantial substitution was much lower than the cost of implementing 100 percent substitution; the cost for substantial substitution may range from Can$2 to Can$4 per metric ton (16

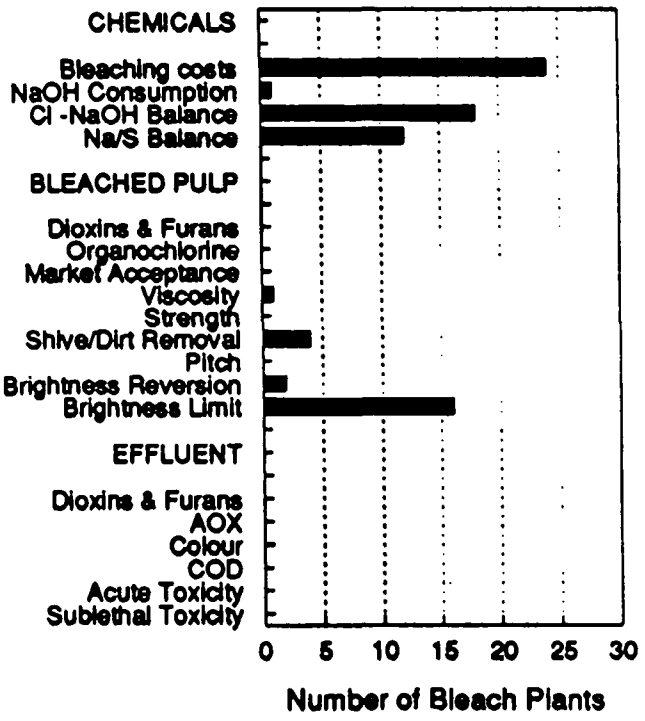

Figure 3.—Disadvantages of 100 percent substitution.

mills). In some cases (11 mills), there was a saving of Can$2 to Can$4 per metric ton of pulp.

The average softwood kappa number for these Canadian mills was 27 — still higher compared to the low lignin pulps of leading edge technologies. Neither oxygen bleaching nor extended delignification are widely practiced in Canada to date. Substantial and 100 percent substitution chlorine dioxide delignification have been adopted much more rapidly because of lower capital costs and benefits more attuned to the needs of the Canadian industry. We are presently expanding this survey to the United States and the rest of the world and expect to have the results compiled in the near future.

Widespread adoption of this technology would be possible with sufficient capital expenditure for conversion or construction to expand chlorine dioxide generation capacity. One potential impediment is the problem of the source of sodium hydroxide for caustic extraction. A nonelectrolysis source must be found to produce chlorine, and sodium hydroxide must be found. Because caustic extraction is always a necessary part of bleaching, this problem is not unique to chlorine dioxide delignification. It applies equally to all non-Cl_2 bleaching. One obvious alternative source is causticization of sodium carbonate incorporated with a lime reburning cycle. The sodium carbonate may be mined or may be taken from the kraft recovery cycle; the lime reburning operations can be remote from the pulp mill or integral with the existing kraft mill operation.

Environmental Factors

Substantial chlorine dioxide substitution's numerous environmental benefits have been extensively described in the literature and validated by mill studies, particularly with respect to dioxins, chlorinated organic compounds, color, and, with less certainty, biological impact. At 100 percent substitution, no dioxins or furans are detected in pulp or in mill effluent, as found in mill operations (Wilson et al. 1991; Morgan et al. 1991).

Highly chlorinated phenolic compounds also decrease with substantial substitution. In one mill operating at 60 percent substitution, an increase to 100 percent substitution resulted in a further decrease in chlorinated phenolic compounds of 94 percent (Wilson et al. 1990). In another mill study, polychlorinated phenolic compounds were nondetectable at 100 percent substitution, with the exception of dichloroguaiacol (Morgan et al. 1991).

Chlorinated organic matter, measured as AOX, also decreases as chlorine dioxide is substituted for chlorine. Furthermore, the character of the material changes as substitution increases, becoming less chlorinated and more oxidized. Most of the material is quite water soluble and has little tendency to bioaccumulate. It has recently been shown that approximately 50 percent of bleach plant effluent AOX is readily photolysed by sunlight to produce chloride ion (Caron and Reeve, 1991).

No attempt will be made in this paper to deal with the considerable controversy about bleach plant effluents and their environmental impact. Chlorine dioxide delignification certainly decreases the discharge of various pollutants of concern and so is a step is the right direction.

When chlorine dioxide is used in pulp bleaching, chlorate ions are formed and will appear in bleach plant effluent. Obviously, increases in the use of chlorine dioxide will increase the formation of chlorate ions. However, chlorate can be readily removed from bleach plant effluent by anaerobic biological treatment or by treatment with sulfur dioxide.

Economic Factors

One of chlorine dioxide delignification's great virtues is that it can be used in existing bleaching equipment at virtually all mills. Some very small piping changes are required and, in some cases, a new mixer may be required. However, existing chlorination stage pumps, piping, mixers, towers, and washers can all be used. This compatibility is a significant savings. Usually, however, increased chlorine dioxide generator capacity will be required, and existing generators must be upgraded

or replaced. For example, the capital costs to increase the generator capacity in Ontario's kraft mills was estimated by McCubbin et al. (1991) to range from Can$2 million to Can$20 million per plant with an average cost of about Can$9 million.

The operating cost of chlorine dioxide delignification will also be site-specific. In some cases, adoption of 30 to 50 percent substitution has been found to decrease costs. However, for 60 to 100 percent substitution, cost increases are to be expected. As noted earlier, the survey found 100 percent substitution costs Can$9 to Can$15 per metric ton of pulp more whereas McCubbin et al. predict cost increases of only Can$3 to Can$9. Implementation of oxygen and extended delignification will decrease operating costs, so long as there are no changes in pulp mill capacity. Both oxygen and extended delignification dissolve more material, which is then recovered and burned in the recovery boiler. If the mill capacity is limited by the recovery boiler capacity, as is often the case, then this extra material can only be recovered at the expense of mill production. This reduction can add significant financial burden to the project.

Pulp quality factors are particularly important for market pulp producers and an extremely important economic factor for all producers. Although brightness ceiling may be a problem for some species, chlorine dioxide delignification provides very high quality pulp. Pulp strength is retained and pulp cleanliness with respect to dirt, shives, and pitch is excellent.

Because chlorine dioxide delignification is the subject of considerable research and development, lower costs and better performance can be expected in the future. Chlorine dioxide delignification is compatible with emerging pulping and bleaching technologies and with bleach plant effluent recovery and treatment technologies. Chlorine dioxide delignification is a valuable part of the solution to pollution prevention; it can provide high pulp quality with low capital cost.

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Bleaching Papermaking Pulps with Oxygen and Ozone in a Commercial Installation

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Ozone has been investigated extensively over the past 15 to 20 years as a chemical to replace chlorine and chlorine dioxide in the bleaching of wood-derived pulp fiber used in making paper and related products. However, its use was never commercialized because of the low strength of the paper and the cost of using ozone in place of chlorine-based compounds.

Ozone Bleaching at Union Camp

Union Camp, in the mid-1970s, launched an intensive research effort to develop suitable technologies to eliminate chlorine-based bleaching chemicals and to make the filtrates from the various bleaching stages compatible with the kraft recovery cycle. In this way, the organic material coming from the bleach plant could be concentrated and burned in the kraft recovery cycle, causing very significant reductions in five-day biological oxygen demand (BOD_5), color, water usage, and chlorine-containing materials, although the latter was not the research's primary objective. Research results led to the use of oxygen before the first chlorine stage on all bleach lines installed by Union Camp since the late 1970s.

By the mid-1980s, the drawbacks of using ozone following an oxygen stage had been overcome in the laboratory. A pilot process tested an ozone bleaching stage on 25 tons per day. The pilot plant's success led Union Camp to commercialize the ozone extended delignification (OZED) bleach sequence for Southern pine fiber at its Franklin, Virginia, mill with startup commencing in July and August 1992.

The OZED (oxygen-ozone-caustic extraction-chlorine dioxide) technology makes most of the filtrates from the various stages compatible with the kraft recovery cycle. Water consumption is reduced, as are pollutants in the bleach plant effluent going to the secondary waste treatment system.

Union Camp's Franklin, Virginia, mill is one of the largest uncoated printing and writing mills in the world, and is located on the Blackwater River, a tidal tributary of the Chowan River. The Blackwater's flows are such that the Chowan is only able to receive well-treated effluent during the late fall and winter months. A hold-and-release ponding system accumulates the effluent for eight months and then releases it in sequence during late November, December, January, February, and early March. This system has been in operation since the mid-1960s with occasional enhancements.

Given the need to conserve water and reduce effluent volumes, in 1970 the company researched and installed a CEDED (chlorine-caustic extraction-chlorine dioxide-caustic extraction-chlorine dioxide) sequence at the Franklin mill. The sequence incorporated full countercurrent recycling of the filtrates, as shown in Figure I. This development cut water usage by more than 50 percent and, as far as I am aware, was the first bleach line to employ this technology.

During the early to mid-1970s, oxygen bleaching was developed in France and Scandinavia and first applied commercially at the South African Pulp and Paper Industries' mill in South Africa. The technology offered significant incentives for reducing BOD_5, chemical oxygen demand (COD), color, and chlorine consumption. Union Camp's inves-

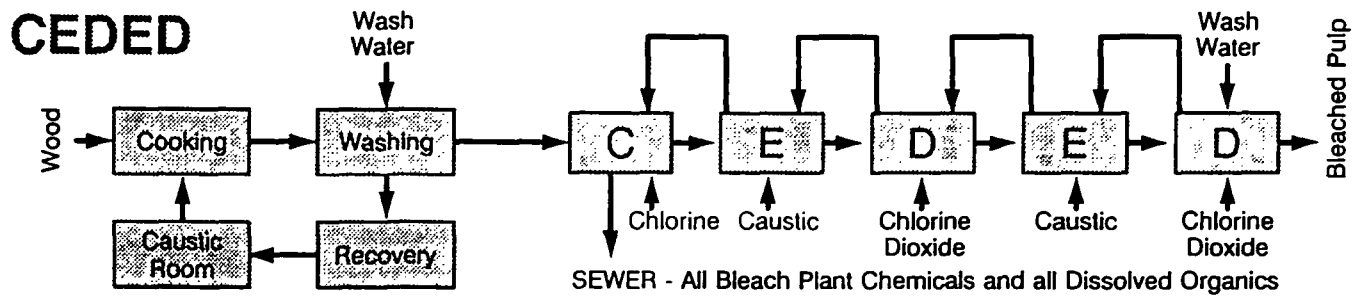

Figure 1.—The CEDED sequence.

tigations of its use on Southern pine and hardwood kraft pulps resulted in the installation of an oxygen-based sequence (see Fig. 2). This installation, a nominal 800 to 900 tons-per-day kraft Southern mixed hardwood bleach line, was started up in 1980, making it one of the first of its kind in North America. About one-half of bleach plant effluent pollutants are eliminated because about half of the lignin remaining in the unbleached kraft pulp is removed in the oxygen stage and recycled to a kraft recovery cycle for evaporation and burning. During the 1980s, we employed the same process to bleach both Southern pine and hardwood kraft pulp at our new Eastover, South Carolina, mill.

Our ultimate goal, however, was to make the filtrates from all bleach stages, where most of the dissolved organics originate, compatible for recycling to the kraft recovery cycle. We wanted to reduce BOD_5, color, and effluent volume. Reduction of chlorinated organics was not an objective but a result of making the filtrates compatible for recycling to the kraft recovery cycle.

The new process is based on ozone replacing the combination of chlorine/ClO_2 in the stage following the oxygen first stage (see Fig. 3). Ninety percent of the organic material removed in the bleaching process is now recycled and burned in the kraft recovery cycle.

Summary and Results

The use of ozone was and continues to be well-researched at the laboratory level. However, ozone was not commercialized until recently because of high chemical cost and the strength of low papermaking pulps. Union Camp overcame these problems in laboratory studies conducted from the late 1970s to the mid-1980s. As noted previously, in 1985, we built a $6 million pilot plant at our Eastover mill. The pilot plant allowed us to get the data necessary to scale up the process; that is, to firm up the reactor design and investigate process parameters associated with filtrate recycling.

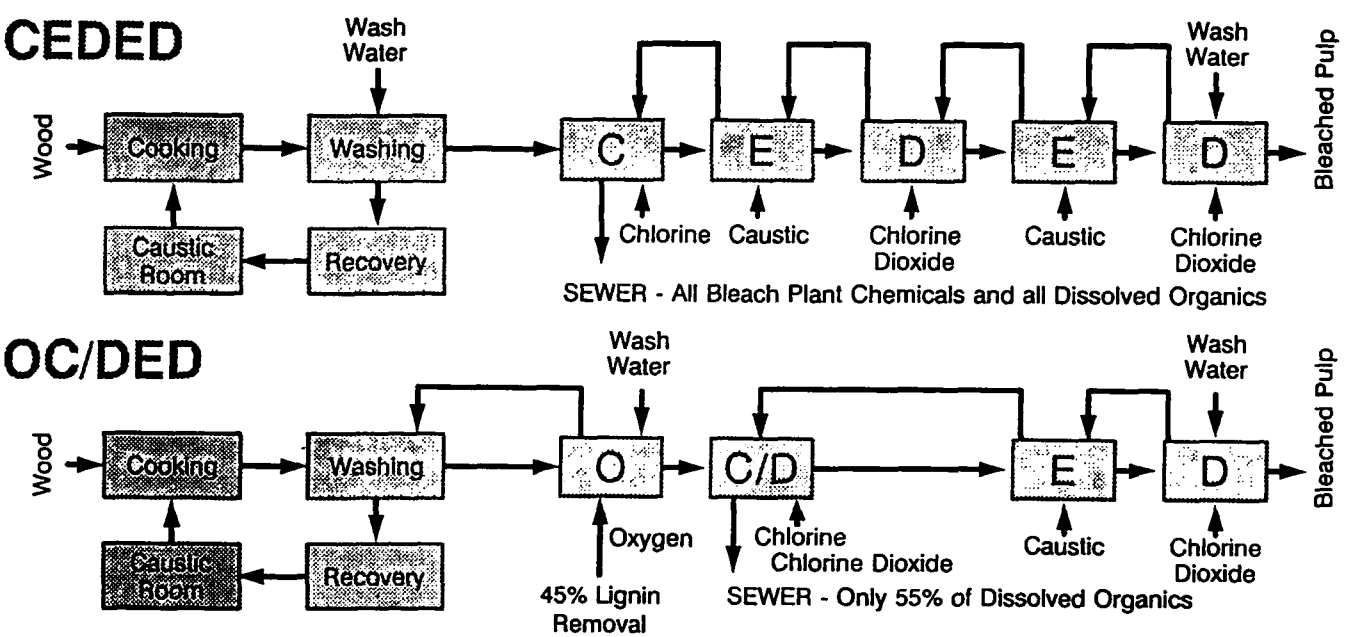

Figure 2.—CEDED sequence and OC/DED sequence.

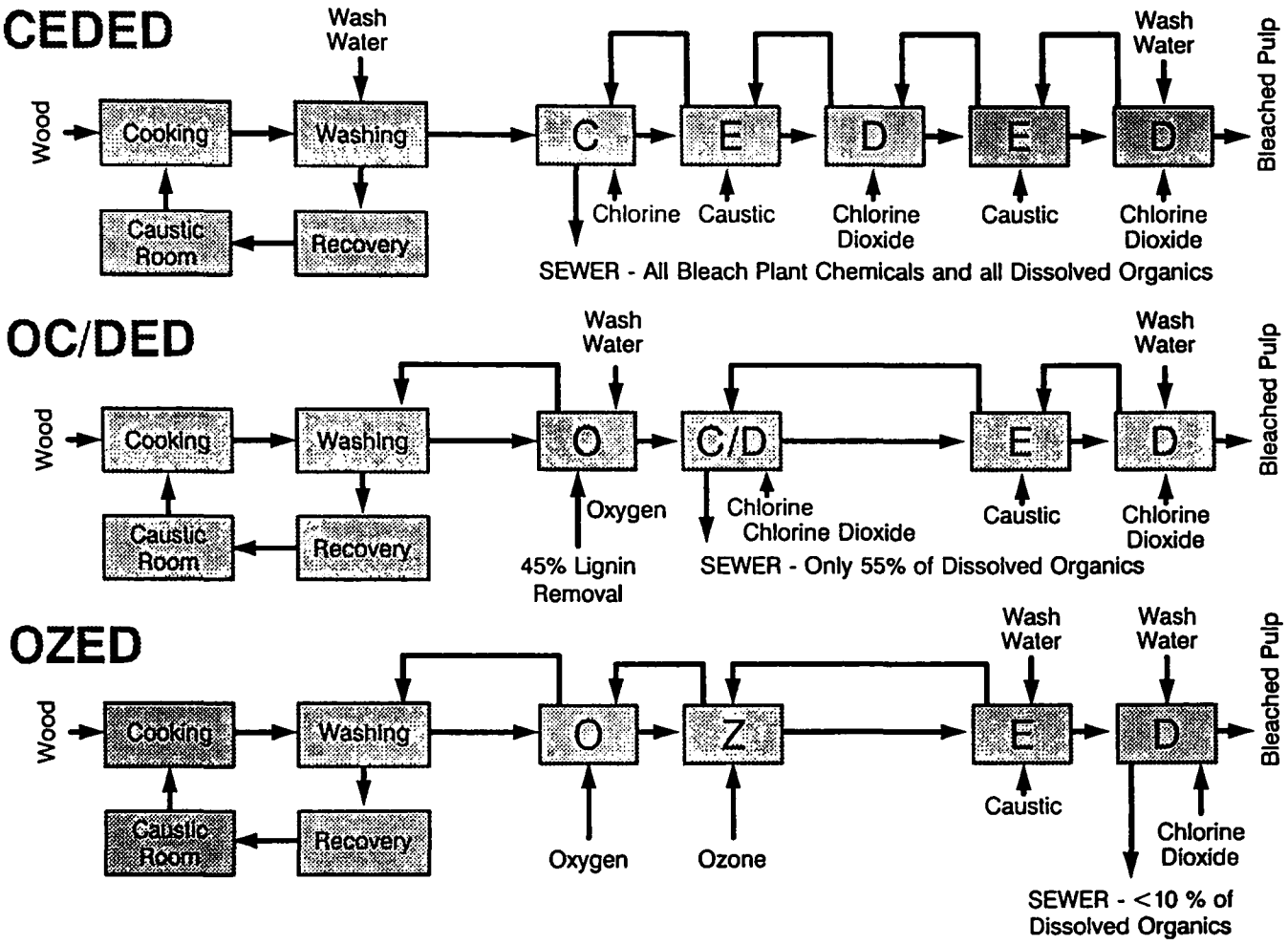

Figure 3.—Adding the OZED sequence.

After about four years of pilot plant studies, Union Camp decided to build the 1,000 tons-per-day softwood bleach line at our Franklin mill that was started up this summer. As far as I am aware, this is the first commercial ozone bleach line with filtrate recycling. There are other ozone bleach lines in various stages of construction, principally being installed to eliminate bleaching with chlorine-containing compounds but in these installations, the dissolved organic materials are still sent to end-of-pipe treatment systems or discharged directly to the receiving waters with no treatment.

The pollution prevention aspects of the process are shown in Tables 1 through 3. Typical values for BOD_5, COD, total organic halides (TOX), chloroform, color, and effluent volume are shown in Table 1 for Southern pine and hardwood pulps. The values are extremely low. Also, dioxin was nondetectable in the pulp and the filtrate from the last chlorine dioxide stage. For comparison's sake, the percent reduction in these parameters versus a CEDED and O(C/D)ED sequences with 30 percent substitution of dioxide for chlorine in the second stage are shown in Table 2 at an 83 GE level of brightness (GEB = General Electric Brightness: the whiteness of pulp versus an absolute standard expressed as a percent). The effluent volume is cut in half. Color, BOD_5, and COD are reduced about 80 to 95 percent or more.

Table 1.—Typical environmental emissions from OZED bleaching to produce 83 G.E. brightness pulp (all but D stage filtrates are recycled).

	PINE	HARDWOOD
TOX*, kg/air-dried ton (ADT), pulp	0.04	0.03
TOX, kg/ADT, effluent	0.075	0.06
Chloroform, kg/ADT	0.0015	0.0015
BOD_5, kg/ADT	2.0	1.0
COD, kg/ADT	6.0	2.0
Color, kg/ADT (chloroplatinate test)	1.5	0.5
Volume of effluent, m^3/ADT	7.5	7.5
Volume of effluent, gal/ADT	1,800	1,800

*Total organic halides (also known as AOX, adsorbable organic halogens)

Table 3 expands the comparison to other wood species at market pulp brightness and a wider range of bleach sequences. The percent reduction in color, BOD_5, TOX, and COD is similar for the

Table 2.—Percent reduction in environmental emissions from OZED in producing 83 G.E. brightness pulp.

	PINE		HARDWOOD	
	COMPARED TO CEDED	COMPARED TO O(DC)ED	COMPARED TO CEDED	COMPARED TO O(DC)ED
TOX*, pulp	86	67	85	77
TOX, effluent	99	98	98	97
Chloroform	99	98	99	98
BOD_5	88	69	88	77
COD	91	73	91	85
Color	99+	96	99+	96
Volume of effluent	86	47	86	47

*Total organic halides

Table 3.—OZED percent reduction in bleach plant effluent 90 G.E. brightness pulp.

		PERCENT REDUCTION WITH OZED			
	COMPARED TO REFERENCE SEQUENCE	COLOR	BOD_5	TOX	COD
Birch	ODEDED	88	76	71	58
Southern hardwood	CEDED	99	88	98	91
Southern hardwood	$O(D_{30}C)ED$	96	78	97	90
Eucalyptus	CEDED	98	87	97	88
Spruce/pine	$O(D_{70}C)EDED$	98	—	97	85
Hemlock/Douglas fir	CEDED	96	91	84	92
Southern pine	CEDED	99	88	99	91
Southern pine	$O(D_{30}C)ED$	96	69	98	73

Table 4.—Tear obtained at a given tensile.

		TEAR, dm[1]		
	G.E. BRIGHTNESS	CONVENTIONALS EQUENCE	OZED SEQUENCE	AT TENSILE, km. of F[2]
Scandinavian birch	89	75	75	6.0
Southern mixed hardwood	88	87	85	6.0
Brazilian eucalyptus	89	88	86	6.0
Scandinavian spruce/pine	89	145	135	7.5
Canadian hemlock/Douglas fir	88	154	161	7.5
Southern pine	88	108	111	7.5

[1]Energy required to tear a piece of paper into two pieces
[2]Force needed to break a piece of paper

various sequences, wood species, and at the higher brightness level.

The strength of pulps bleached with this sequence, or slight variations of it, is comparable to the strength resulting from a basic CEDED sequence or its variations that incorporate oxygen as a first stage. Strength becomes harder to maintain as brightness is increased, but even in the market pulp brightness range, tear at tensile is equal for pulps from several different wood species (see Table 4). We have data in the 83 GEB range for southern pine that also show strengths comparable to OC/DED sequences.

At this point, based on laboratory and pilot plant work, we believe that the basic sequence shown, or variations of it, can produce bleached pulps with acceptable strengths over a brightness range that includes market pulp brightness and on the wood species of commercial interest around the world.

A logical question is whether the last chlorine dioxide stage can be replaced with a hydrogen peroxide stage. The most I am willing to say at this conference, based on laboratory work, is that modifications to the basic ozone sequence can be made to incorporate hydrogen peroxide. This modification makes the process chloride ion-free at increased cost and with some limitations on the range of brightness at which strengths are comparable to pulps produced with conventional sequences. It is easier with some wood species than others to make acceptable pulps using hydrogen peroxide.

Variable and Capital Costs

Union Camp has found variable and capital costs to be quite site-specific and dependent on what costs can be avoided in other parts of the operation outside the bleach plant proper. The percent reduc-

Table 5.—OZED percent reduction in bleaching chemical costs to produce 90 G.E. brightness based on raw material costs.

	CONVENTIONAL BLEACHING		100% SUBSTITUTION	
	REFERENCE SEQUENCE	% REDUCTION	REFERENCE SEQUENCE	% REDUCTION
Birch	O(DC)EDED	42	ODEDED	47
Southern hardwood	CEDED	20	DEDED	52
Eucalyptus	CEDED	16	DEDED	46
Spruce/pine	O(DC)EDED	35	ODEDED	32
Hemlock/Douglas fir	CEDED	38	DEDED	61
Southern pine	CEDED	55	DEDED	68

tion in bleaching chemical cost to produce 90 GEB pulps using different sequences are shown in Table 5. As chlorine dioxide is substituted for chlorine, the reduction in bleaching chemical cost can be as much as 68 percent on Southern pine. Typical market prices were assumed for the various chemicals except ozone, where the on-site generation cost was most appropriate.

Capital costs for the ozone stage and the ozone generation equipment generally adds 20 to 30 percent to the capital cost for the bleach line over an OC/DED sequence. However, it is frequently possible to offset most, if not all, of this added cost through elimination of chlorine unloading and handling systems, a smaller ClO_2 plant and smaller end-of-pipe waste treatment facilities. No additional evaporator capacity is required, and only 3 percent more recovery boiler capacity is required over oxygen-based sequences. For a new mill or a significant expansion of an existing site, the capital costs may well be equivalent. Clearly, this analysis of the pollutant abatement advantages and average variable and capital costs associated with ozone bleaching suggest that it will be a commercially important technology for bleaching kraft pulp.

Saving Bleaching Chemicals and Minimizing Pollution with Xylanase

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The use of chlorine in pulp bleaching is a source of environmental concern since the process results in a discharge of chlorinated organic compounds to receiving waters. In response to this concern, the international pulp and paper industry is modifying or completely changing its bleaching technology. The trend is to reduce the use of elemental chlorine by substituting chlorine dioxide, thereby preventing the formation of dioxins and minimizing the production of other organochlorine compounds (Berry et al. 1989). In addition, several new processes are being developed to eliminate the use of chlorine chemicals and to bleach pulp using only oxygen, hydrogen peroxide, ozone, or other chemicals (Liebergott et al. 1984). These alternative processes are more expensive and may damage pulp strength and other properties if used at high chemical charges.

Xylanase Works with a Variety of Bleaching Processes

Biotechnology is playing a role in the transition to chlorine-free bleaching. Viikari et al. (1986) discovered that a brief treatment of pulp with the enzyme xylanase enhances pulp bleachability. The effect is illustrated in Figure 1. In this case, pretreatment of the softwood pulp with xylanase resulted in 15 to 25 percent savings of chlorine needed to bleach pulp, with an average saving of about 15 percent. Xylanase's efficacy seems to be correlated with its ability to depolymerize xylan, a normal component of pulp. The xylan may entrap or covalently bond the lignin chromophores in the pulp.

The mechanism proposed by Paice et al. (1992) is illustrated in Figure 2. Depolymerization of xylan allows lignin to diffuse more easily from the fiber wall. As a result, lower charges of bleaching chemicals can remove lignin to a desired degree. This mechanism allowed us to predict that xylanase will aid bleaching not only with chlorine but also with other bleaching chemicals, and its efficacy has now been confirmed in bleaching sequences using chlorine dioxide, oxygen, hydrogen peroxide, and ozone.

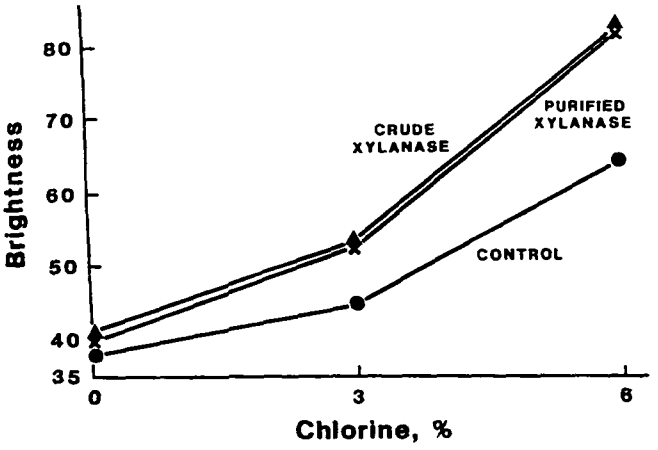

Figure 1.—Effect of xylanase on subsequent chemical bleaching of black spruce kraft pulp. Initial Kappa number = 30.1. (From Paice et al. 1992).

Applying Xylanase in a Mill

The application of xylanase in a mill is very simple — usually only a small laboratory pump is needed to deliver the enzyme solution at a flow rate of ap-

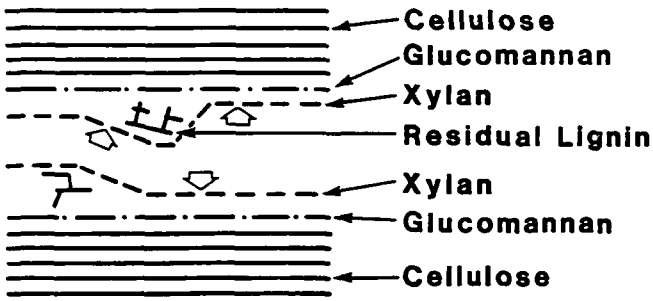

Figure 2.—Proposed structure of secondary wall of unbleached kraft pulp, based on model of Page (1976). Arrows show sites of xylanase attack. Subsequent opening up of the xylan structure results in increased diffusion of residual lignin and decreased size of lignin-carbohydrate fragments. (From Paice et al. 1992).

proximately 1 liter per minute to the pulp system. It is also necessary to adjust the pH levels to a range compatible with the enzyme activity, somewhere between four and nine. Estimates for the capital cost of enzyme delivery and pH adjustment vary from Can$10,000 to Can$100,000. Some mills already adjust the pH levels to minimize pitch problems. In these mills, the capital cost is even lower. Figure 3 shows an example of a system used recently in a Canadian mill in which the Pulp and Paper Research Institute of Canada conducted a trial with a commercial enzyme supplier (Scott et al. 1992).

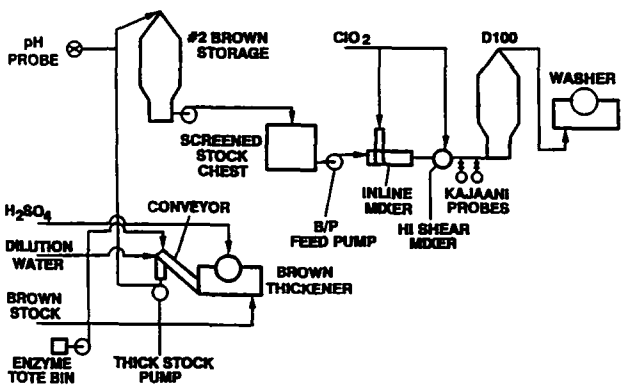

Figure 3.—Process equipment for Canadian mill trial with 100 percent chlorine dioxide substitution. (From Scott et al. 1992).

The pH level of the pulp was adjusted to 5.5 by adding sulfuric acid through a shower after pulp washing, and the enzyme was added to the repulper. Additional mixing was provided by a high consistency pump and the enzyme reaction took place in the brownstock storage tower during its normal retention time of 1.5 hours at 55°C. As soon as the enzyme worked its way through the pulp system, pulp brightness sensors registered an increase (after the third bleaching stage). This result allowed the setpoint of chlorine dioxide sensors to be lowered. Thus, the chlorine multiple was decreased from 0.265 to an average of 0.19. The lowest chlorine multiple tested was 0.173 and yet the plant continued to produce fully bleached pulp. Reduction of the chlorine multiple led to a decrease of adsorbable organic halogens (AOX) emission from 0.95 to 0.75 kg per air-dried finished ton (ADFt) (see Fig. 4), based on samples taken after the biotreatment basin.

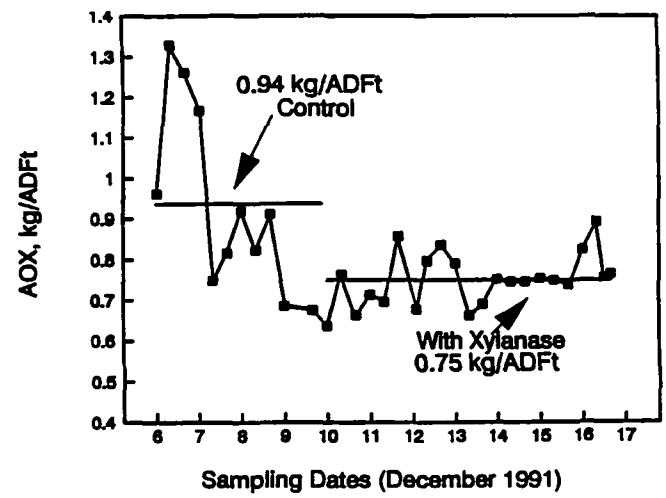

Figure 4.—Total bleach plant effluent AOX after 24-hour biotreatment in a biobasin. (From Scott et al. 1992).

The reduction of AOX emissions was proportional to the decreased charge of chemicals needed to accomplish pulp bleaching to a given brightness. Strength of fully bleached pulp was measured during the mill trial and no changes were observed when compared to a control period before the trial. Thus, the application of xylanase resulted in chemical savings and reduction of pollutants while fully maintaining the pulp quality.

Positive results were also reported from mill trials with chlorine-free technologies. Genencor International reported recently that in a bleaching sequence employing oxygen and two alkaline peroxide extractions, the pulp brightness increased by 2 to 4 points with no adverse effects on pulp strength.

The quality of the enzyme and the process conditions are an important consideration. Overdosing with the enzyme may result in unacceptable pulp yield loss. Contamination with traces of cellulase can severely damage pulp strength and must be avoided.

Xylanase is available in industrial quantities from several commercial suppliers. Table 1 lists sources that are known to us at this time. The enzymes are sold as concentrated liquids and the amount required for a ton of pulp is therefore very small. The enzyme cost per ton of pulp is variable and depends on dosage required. The economy of

Table 1.—Industrial xylanase suppliers (alphabetical list).

SUPPLIER	PRODUCT	OPTIMUM pH	OPTIMUM TEMPERATURE (°CELSIUS)
Alko, Biotechnology Division, Finland Tel. in Canada: (416) 881-9639	Ecopulp	5–6	55
Genencor International, Inc., U.K. Tel. 44-737-773732	Albazyme 10 Albazyme 40	6–7 7.5	60 65
Iogen Corp., Canada Tel. (613) 733-9830	Xylanase (two types)	5–6 7–8	55 55
Novo-Nordisk Bioindustrials, Inc., USA Tel. (203) 790-2671	Pulpzyme HA Pulpzyme HB	5–6 7–8	55 55
Sandoz Chemicals, USA Tel. (704) 331-7334	Cartazyme HS	4–5	50
Voest-Alpine Industrieanlagenbau, Austria Tel. 43-732-592-3681	Xylanase production line	6–7.5	65–75

Table 2.—Xylanase technology status (approximate data).

Commercial use	10 mills total; 6 in Europe, 4 in Canada.
Mill trials	85 altogether; 45 in Europe, 24 in Canada, 15 in the United States, one in Japan.
TCF vs. chlorine bleaching	Most xylanase trials were in combination with chlorine/chlorine dioxide bleaching technologies. Trials with totally chlorine-free technology are on the increase.
Softwood vs. hardwood	15 mill trials were with hardwood, the remaining 70 with softwood.
Kraft vs. sulfite	Only one mill trial was performed in a sulfite mill.

the process improves in combination with high chlorine dioxide substitution levels. Table 2 summarizes the current commercial state of the technology. It is evident that the process is gaining acceptance particularly in Europe and in Canada, and that xylanase will become more and more common in the paper and pulp industry worldwide over the next few years.

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Panel 4:
Alternative and Emerging Technologies — Bleaching

Question and Answer Session

■ **Med Byrd,** *North Carolina State University:* I would like to direct this question to Dr. Jurasek and Dr. Axegård. It seems that the beneficial effect of enzymes depends on whom you ask, on whether the person is working with enzymes or not. People who are working with enzymes show a beneficial effect and, indeed, mill applications and trials are going on at a pretty good clip. However, when you talk to the people working with the more conventional nonconventional bleaching agents, like ozone, chlorine dioxine, oxygen and peroxide, they will say, as Dr. Axegård pointed out, that enzymes add little or no benefits to a modern bleach sequence. Can you help explain the disparity in these views that we hear all of the time?

■ **Lubomir Jurasek,** *Pulp and Paper Research Institute of Canada:* It is reported that the use of enzymes allows one to decrease the chemical charge of chlorine dioxide and chlorine by about 20 percent with oxygen; with hydrogen peroxide and ozone, enzymes are somewhat less effective, so the chemical charge decrease is only about 10 percent. This may be due to the state of . . . in the pulp and the mechanism of the bleaching. But what off-sets the decreased efficiency of the enzyme is the increasing price of the chemicals being used as chlorine substitutes. With chemicals such as ozone, one tries to keep the concentrations and charges as low as possible because of the possible danger of viscosity of the pulp — any help from xylanase is appreciated.

■ **Peter Axegård,** *Swedish Pulp and Paper Research Institute:* Maybe we have compared different systems. We can assume that enzymes are quite large molecules that are basically directly on or close to fiber surfaces. So in systems in which you have precipitation of lignin and carbohydrates, enzymes are quite likely to help. For instance, if you are losing pH or alkalinity, you may be helped by enzymes. Such cases are quite common, but in my mind, they are a poor reference. Enzyme use is experimental.

■ **Norman Liebergott,** *DuPont Canada, Inc.:* I have two questions. Peter, you picked the sequence OQ(EPO)Z(EP) as your best one. But I don't understand why you put the Q in that certain spot. Is it to improve or enhance the EPO? But we also found that a small Q before the Z, enhances the Z, or after the Z will enhance the second EP, there is still left . . . in the pulp that for some reason the ozone does not get moved.

■ **Peter Axegård:** I guess there is some truth in what you say. The sequence can be developed. That's one answer.

■ **Norman Liebergott:** There are many answers. The same thing I'm pointing out to Imo there. When you looked at your sequence and replaced the chlorine dioxide, should we say with ozone, if you also look at the gain before peroxide stage, you find that after the Z stage, a chelation stage is very important. Have you tried that in your lab or pilot plant?

■ **William Trice,** *Union Camp Corporation:* I think we have tried just about everything in the lab. I am not sure that I want to comment on that. I think

most people have found that chelation of metal ions is a necessity for peroxide bleaching. I really don't think that there is any evidence to change that.

■ **Lubomir Jurasek:** But many people think that if you are doing an ozone stage at lower pH (and most people do), that this would remove the metal ions, but unfortunately it doesn't. This is why when people say they can recycle the whole ozone effluent without going backward and . . ., I say good luck to you because the metal ions do build up in the system.

■ **William Trice:** How you handle the filtrates is a significant part of the technology. It is not as easy as it looks, I'll give you that.

■ **Lubomir Jurasek:** The last question was about using enzymes. Enzymes have a certain effect on certain bleaching sequences at a certain cost rate. It depends on what you want to spend and what you want to get. Some people have said that a one or two point brightness gain for a TCF sequence is very important because they must maintain brightness and for that they would or would not use enzymes.

■ **Mark Floegel,** *Greenpeace:* I have a question for Douglas Reeve. Traditionally, technology in the pulp and paper industries has been slow to change but I think most people would agree that change is becoming rapid. You were talking about chlorine dioxide substitution as being driven by reductions in AOX and market pressure. Then you noted that one of the highlights of the chlorine dioxide substitution is getting the company to invest in a large generator system. Given the market pressure that I'm reading about in the trades today, the already burgeoning market for TCF pulp and British Columbia's zero discharge regulation for the year 2002, aren't you recommending a 20-year investment for a 10-year technology?

■ **Douglas Reeve,** *Pulp and Paper Centre, University of Toronto:* No. I am not persuaded that the universe will unfold as you have described. I am not persuaded that the British Columbia zero discharge regulation will stick by the year 2002 — just as the ban on nuclear power in Sweden is unlikely to stick — because many economic realities have to be faced before that time. I think the development of the TCF pulp market in North America remains to be seen. Who knows whether North American consumers will accept the higher costs and lower quality for TCF pulps? I think that remains to be seen.

■ **Mark Floegel:** The question that I am asking is whether you are asking the industry to take that gamble. You have a version of the way the world will unfold and so do I, but in the balance is a very expensive investment.

■ **Douglas Reeve:** I am describing what has taken place in Canada and I am describing an alternative for modifying a bleaching sequence to solve part of the problem of pollution prevention.

■ **Richard E. Phillips,** *International Paper:* We have run numerous mill trials and literally dozens of laboratory experiments on every commercially available enzyme. And their effect, if they have any effect at all, is less than 10 percent. I suggest that we may be more technologically advanced. I think, as Peter Axegård pointed out, the better your oxidative extraction stage is, the better your first bleaching delignification stage is, the less effect you will see with enzymes. In addition to that I would submit that those people who practice extended delignification are probably removing much of the lignin that is potentially soluble by virtue of the enzymes that may be acting on the hemicelluloses in preventing the lignin to come out. So we do not see much effect and we are not very excited about enzymes. We don't see them as cost effective at this point — but for a different reason from the one that your Canadian colleague has proposed.

■ **Bruce Fleming,** *Boise Cascade:* Peter, on one of your earlier slides, you had the words, "TCF Market Pressure." Mr. Floegel just referred to it again. I would like to investigate what this market pressure is. We hear a lot about market pressure, and yet I understand in Sweden, when the Aspa company started making TCF pulp, the . . . pulp mill had to take downtime for inventory control and they were only making about 200 tons a day of TCF pulp. What is the depth in the TCF market, and is there really any pressure there?

■ **Peter Axegård:** There is definitely an interest larger than the current volume. One of the reasons Aspa discontinued production was that they had a competitor, I think, of higher quality. They went back to chlorine dioxide bleaching because there were other producers of TCF that made better quality.

■ **Bruce Fleming:** Can you give us an estimate of the amount of TCF pulping in Sweden?

■ **Peter Axegård:** I think it is quite small. I couldn't guess, but let's say around 5 percent of the bleached kraft pulp. A session tomorrow or the day after may bring this topic up again.

■ **Ken Wiesner,** *Wisconsin Department of Natural Resources:* In Wisconsin, the industry emits about a million pounds of chloroform annually. Most of our discussions have focused on reducing dioxins and furans, and since we seem to whip that problem, maybe we could move on to the other. The question I have is whether the process modifications we're making that primarily focus on dioxin and furan reduction are also as effective in trying to knock down the chloroform emissions. These come off the bleaching stages as well as releases to the biological wastewater treatment plan.

■ **Douglas Reeve:** As you increase substitution in the chlorination stage, chloroform production is dramatically decreased, and chloroform is certainly not manufactured in the treatment plant. If it is manufactured in the chlorination stage or the hypochlorite stage, which is where it has previously been manufactured in greatest amount, then it would be blown out in the treatment plant. So. If it's not manufactured when you use substantial substitution, it's not going to appear in the treatment plant.

■ **Ken Wiesner:** Is chloroform measured as part of AOX?

■ **Douglas Reeve:** No, it is not.

■ **Norman Liebergott:** May I return to Doug Reeve and his friend from Greenpeace. A lot of the Canadian mills are looking at using a small D stage up front, that is, using chlorine dioxide in a lower amount than you would normally use for complete delignification. Then a very strong EOP stage would be used followed by a PDP or a DPP or whatever you want to call it. This sequence can produce 89 to 90 brightness pulp, with very low levels of AOX — in mill trials sometimes as low as .5 or .4. This produced very good pulp and had very good effluent qualities, too. So when people say that they are still thinking about investing in chlorine dioxide, there's still something there, I think.

■ **Neil McCubbin,** *N. McCubbin Consultants, Inc.:* Permit me to mix a question and a comment. With respect to TCF pulp capacity, my figures point to a capacity of 3-million tons per year for totally chlorine-free bleached kraft pulp; and to sales of about half a million tons per year. Now, these figures disagree with the oft-repeated statement by Greenpeace that if the nasty old industry would only make totally chlorine-free pulp, the world would rush to buy it. I wonder if anyone can throw out better figures than mine — which I got by phoning around prior to a meeting three weeks ago. Can someone come up with better numbers particularly for TCF sales? Is half a million a good estimate?

■ **Ladd Seton,** *Fraser Paper:* You are stealing my thunder. The day after tomorrow we have a session on market pulp and these are, in fact, the topics that I plan to address. And I believe that you are asking a very valid question. I think the market question is very important, so please come on Thursday afternoon.

Wednesday, August 19, 1992

TRADE-OFFS, PERFORMANCE, AND GOVERNMENT ACTIVITIES

PANEL 1: **Trade-off Issues**

PANEL 2: **Technical Perspectives — Specifications**

PANEL 3: **Technical Perspectives — Performance and Cost**

PANEL 4: **Government Activities**

PANEL 5: **EPA Activities**

The Properties of Pulps Bleached in Low-Chlorine or Non-Chlorine Sequences

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Special Consultant
DuPont Canada, Inc.
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Commercial bleaching sequences applied to chemical pulps have shown many improvements in the last 20 years. They produce acceptable products while conforming more and more with energy and environmental restrictions. The increased use of chlorine dioxide, oxygen, and hydrogen peroxide are apparent in improved bleaching stages. Better equipment design is also improving the technology of bleaching. New mixers, new washers, medium-consistency equipment and better control systems improve the efficiency of the bleaching process. With all this activity in the pulp manufacturing area, three questions arise: (1) Why should pulp be bleached? (2) Why is pulp bleaching technology changing? and (3) What are the best bleaching sequences?

1. Natural fibers (from wood or other sources) obtained from a pulping process vary from a manila white to a dark brown depending on the pulping process. The colored material in the pulp comes from lignin and its reaction products, resins and degraded polysaccharides. There are many answers to the question why we bleach but to me "to make the pulp suitable for the desired end use," is the primary one.

2. Pulp bleaching technology is changing because of environmental concerns. The North American pulp and paper industry is committed to making changes in the bleach plant to suppress the discharge of undesirable by-products into the receiving water environment. The by-products of particular concern are chlorinated organic compounds formed during a chlorination stage in which molecular chlorine is the main bleaching constituent. Their elimination naturally hinges on using less chlorine in the bleach plant (Berry et al. 1991). Several options are now commercially viable that can decrease the chlorine usage in the bleach plant; see, for example, Axegård et al. 1991; Basta et al. 1990; Bowen and Hsu, 1990; and Liebergott et al. 1991. The most common option is to use chlorine dioxide instead of chlorine in the chlorination stage (Pryke et al. 1991). By resorting to oxidation reactions to delignify the pulp, the resulting effluents contain less adsorbable organic halogens (AOX) and the chlorolignins are considerably less toxic than those produced when bleaching with molecular chlorine (Berry et al. 1991; Liebergott et al. 1991).

3. The choice of a bleaching sequence and the technology for such a sequence depends on

(a) Whether the species is wood or nonwood;
(b) The cooking process;
(c) The chemical, physical, and optical qualities desired in the bleached pulp;
(d) The quality of the effluent (whether it meets no-detect levels for dioxins or furans, has low or no AOX and chloroform, and low chemical and biological oxygen demand [COD] and [BOD] and color);
(e) Whether primary, secondary, or tertiary treatments of the effluent are available;
(f) Whether the recovery boiler has excess capacity;
(g) The present bleaching sequence;
(h) What equipment can still be used; and
(i) How much new capital funds are available.

Table 1.—Typical pulp strength characteristics.

	ACID SULFITE	BI-SULFITE	HIGHYIELD SULFITE	ALKALINE SULFITE	KRAFT
Burst Index kPa.m²/g	4.5 -7.5	6.0 - 8.0	3.0 - 6.0	8.0 - 10.0	8.0 - 10.0
Tear Index mN.M²/g	7.5 - 9.5	8.5 - 9.5	8.0 - 11.0	10.0 - 12.0	10.0 - 12.0
Tensile meters	7,5000 - 8,5000	10,5000 - 11,500	3,500 - 6,500	11,000 - 12,000	11,000 - 13,000

all at freeness 300 CSF

The objective of this paper is to consolidate the various new pulping and bleaching processes and evaluate the effluent properties and the pulps. This evaluation will help particular mills select the most appropriate sequence.

Kraft Pulping and Bleaching

Some typical pulp strengths for a spruce and balsam pine mixture produced by different pulping processes are shown in Table 1. The kraft pulping process produces pulp with high strength characteristics that can sometimes be equalled by the alkaline sulfite pulping technique.

The initial removal of lignin is accomplished in the cooking process. However, these pulping processes cannot completely remove the lignin without seriously degrading the carbohydrate fraction and affecting the yield and strength of the pulp. Bleaching is a continuation of the pulping process and chlorine is usually used in the first bleaching stage. This use of excessive quantities of chlorine has led to concern for the environment, and different strategies to decrease the chlorine have been used.

Because the quantity of chlorine necessary to bleach pulp is a function of the kappa number of the pulp, a lower kappa number before the chlorination stage means lower chlorine usage (Liebergott et al. 1991). Several methods can be used to decrease the kappa number of the brownstock.

Extended Delignification

Conventional kraft pulping produces bleachable grade pulps at kappa numbers of 28 to 32 on softwoods and 15 to 22 on hardwoods. Lower kappa numbers can be obtained by modifying the pulping process to improve the selectivity of delignification.

Extended delignification, such as modified continuous cooking (MCC) (Macas et al. 1991), rapid displacement heating (RDH) (Andrews et al. 1991) or extended SuperBatch kraft™ cooking (Boman et al. 1991) decreases the kappa number of the brownstock and hence the chlorine charge (Fig. 1). These techniques are presently operating in several Canadian and U.S. mills. Sulfite pulping can also be modified to decrease the kappa number.

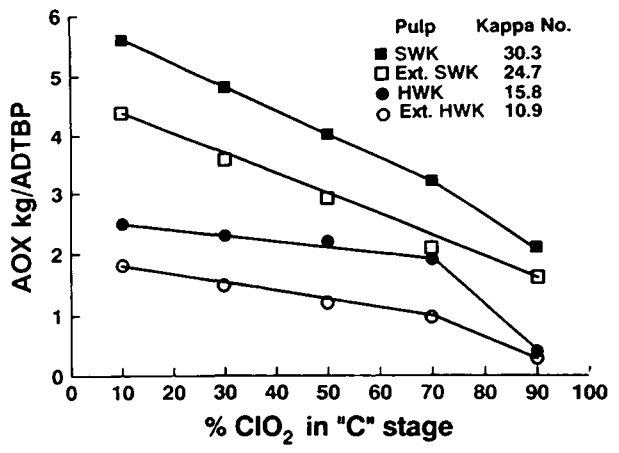

Figure 1.–Less AOX is formed in the bleach effluents when a pulping process delignifies to lower kappa numbers, and when more chlorine dioxide instead of chlorine is used in the C-stage.

Oxygen Delignification

Oxygen-type delignification in prebleaching stages (O, EO and EOP) decreases the kappa number prior to chlorination and thus the effluent loading (BOD, COD, color, AOX, chlorinated phenolics and toxicity to fish) emanating from the bleach plant (Liebergott et al. 1991). The delignification expected from the various oxygen-reinforced stages is shown in Table 2. An oxygen-type delignification may decrease the kappa number of softwood kraft pulp from 30 to a range as low as 16 to 22 and thus decrease the AOX in the effluent of a $(C_{90}+D_{10})$(E-O)DED bleaching sequence from 6 kg per tonne to 3.9 (Fig. 2).

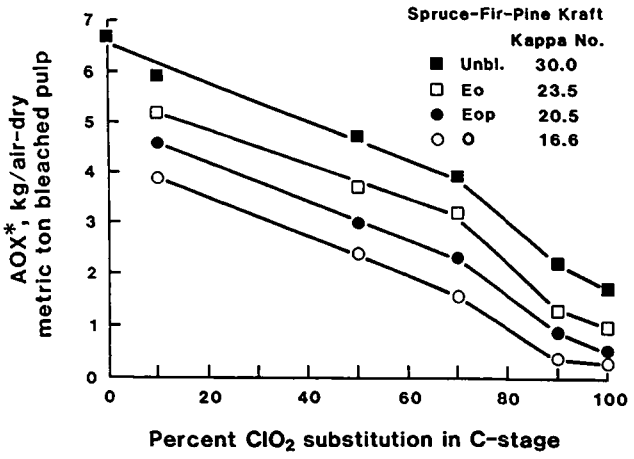

Fig. 2 Less AOX is formed in the bleach effluents when the pulps are delignified to lower kappa numbers, and when more chlorine dioxide instead of chlorine is used in the C-stage.

Table 2.–Type and Efficiency of Pre-treatment Stage

STAGE	POSSIBLE DECREASE IN KAPPA NO. OF BROWNSTOCK
P	20%
EO	25%
EOP	30-35%
O	40-50%

Enzyme Pretreatment

The concept of using a hemicellulose to improve pulp bleaching was originally presented in 1986 (Viikari et al. 1986). Many other reports followed showing that laboratory treatments of brownstock with selected enzymes of the hemicellulytic type, particularly xylanase, hardly affect the kappa number of the pulp (Liebergott and van Lierop, 1978; Liebergott et al. 1984; LaChenal and Taverdet, 1991; Lindholm, 1991). The chlorine requirement, however, decreases by about 30 percent to achieve the same "C"Eo kappa number as its untreated counterpart. This recent technology has been successfully tried in 10 mills. Apparently, the xylanase modifies the hemicellulose such that the chlorine is capable of removing a greater fraction of the lignin. Xylanase pretreatment does not affect pulp strength.

Decreasing the Kappa Factor

The most efficient bleaching is obtained by removing the bulk of the lignin in the first chlorination and extraction stages. This removal is accomplished by applying a specific quantity of chlorine which is related to the kappa number of the pulp entering the stage. This chlorine requirement is conveniently expressed as kappa factor or active chlorine multiple, which is derived from the total active chlorine charge (expressed as percent on oven-dry pulp) divided by the kappa number of the pulp entering the chlorination stage. Thus, an unbleached pulp at a kappa number of 30 would require a charge of 6.6 percent active chlorine on pulp, based on a kappa factor of 0.22.

A decrease of the kappa factor from 0.22 to 0.17 can be accomplished by reinforcing an oxidative extraction stage with peroxide (Eop). By improving the efficiency of the extraction stage, less chlorine is required in a "C"(Eop) process than "C"(Eo) to achieve the same kappa number (Table 3). Magnesium sulfate should be added to the Eop extraction to retain pulp strength (see Fig. 3).

Table 3.–Varing the active chlorine multiple in "C."

"C" Eo-STAGE TYPE	ACM	PROPERTIES AFTER "C" Eo KAPPA NO.	AOX kg/ADTBP
(C_{90} + D_{10}) Eo	.22	3.4	5.6
(C_{90} + D_{10}) Eo	.17	5.1	4.4
(C_{90} + D_{10}) Eop	.17	3.8	4.6
($D_{50}C_{50}$) Eo	.22	2.8	3.7
($D_{50}C_{50}$) Eo	.17	4.8	2.8
($D_{50}C_{50}$) Eop	.17	2.7	2.7
4.0 kb H_2O_2/t pulp in Eop			

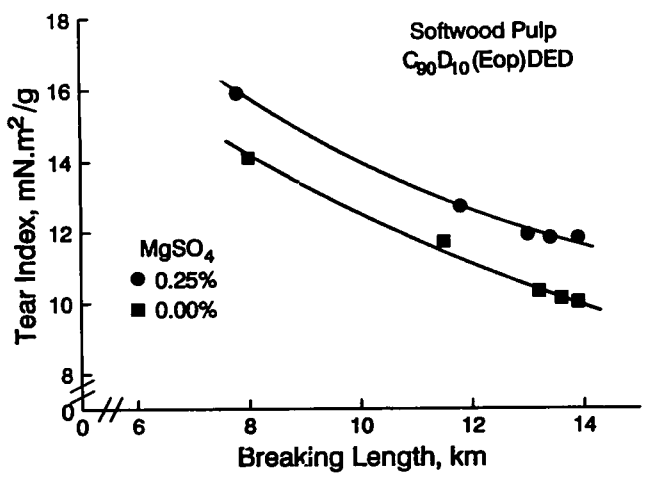

Figure 3.–Effect of $MgSO_4$ in the EOP stage on pulp strength.

High Chlorine Dioxide Substitution

An increase in the substitution of chlorine dioxide in the chlorination stage from 50 to 100 percent in the (Dc)(Eo)DED sequence also decreases the chlorinated phenolic compounds, color, and AOX in the effluent and eliminates a large portion of the toxicity to fish (see Fig. 2). High chlorine dioxide substitution (70 to 90 percent) does not, however, substantially lower the BOD and COD values of the effluent. One hundred percent chlorine dioxide substitution in the chlorination stage decreases the

AOX in the effluent by 70 to 80 percent and the chlorinated phenolic compounds by 95 percent.

Several mills have tested this technology and confirmed the laboratory results (Pryke et al. 1991). High substitution of ClO_2 (100 percent) increases the "C"(Eo) kappa number which in turn causes lower brightnesses after DED brightening. Using peroxide in the oxidative extraction and the E_2 stages can overcome the deficiencies of high ClO_2 substitution. Magnesium sulfate added to the Eop and E_2 stages protects pulp viscosity (Table 4). As the ClO_2 generation capacity expands, more mills will use this technique to comply with environmental regulations.

Table 4.—D_{100}Eo and D_{100}Eop delignification of a softwood kraft pulp

Kappa No., 29.5; Viscosity, 41.0 mPa.s

Extraction Stage Type	H_2O_2 %	$MgSO_4$ %	KAPPA NO.	VISCOSITY mPa.s	AOX kg/ADTBP	CHLORATE kg/ODTP
Eo	0	0	4.6	35.5	1.51	4.68
Eop	0.4	0	3.2	28.7	1.59	4.64
Eop	0.4	0.05	3.3	34.9	1.58	4.63

Conditions: D_{100}; Consistency, 3.5%; 40 mins.; 40°C; pH2.3. Active Chlorine Multiple, 0.22; D charge, 2.46%, ClO_2 on pulp O.D. basis.
Eo and Eop, Consistency, 10%; 60 mins.; 60°C; O_2 pressure, 20 psig for 10 mins.; NaOH charge, 2.30%.

The effect of three different bleaching techniques on the tear breaking length relationship of a softwood kraft pulp are shown in Figure 4. Lowering the chlorine multiple using D_{100} and an enzyme as a prebleaching stage did not affect the strength relationship; all the points fell on the same curve.

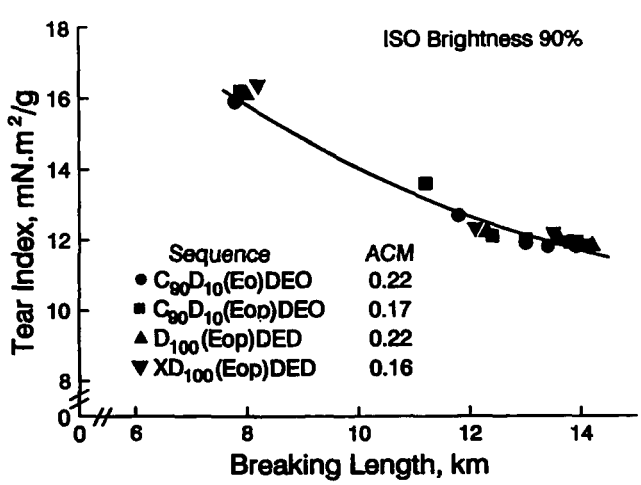

Figure 4.–The effect of different bleaching sequences on pulp strength.

Elimination of all Chlorine Compounds

Concern over the presence of chlorinated organic compounds in bleach effluents is leading the industry to examine alternatives to chlorine-based compounds in the pulp bleaching process. Chlorine compound-free bleaching sequences would most likely incorporate combinations of stages using chemicals such as those shown in Table 5. None of the combinations reported to date, however, can be applied commercially with the same efficiency and producing the same pulp quality as do sequences containing some chlorine-based chemical, notably chlorine dioxide, which is far less problematic than molecular chlorine.

Table 5.–Alternatives to chlorine compounds

Oxygen	Hydrosulfite
Peroxide	Chelating Agents
Ozone	Thiourea dioxide
Peracetic Acid	

Oxygen-Peroxide Bleaching Sequences

It is anticipated that a totally chlorine-free (TCF) bleaching process will rely mainly on an efficient delignification and peroxygen compounds to increase the brightness of an unbleached pulp. Hydrogen peroxide is used extensively to brighten mechanical pulps, and its successful application depends on a chelating step to remove metal ions that promote rapid decomposition of the active perhydroxyl ion. The conventional chlorine-containing bleaching stages are known to remove metal ions; therefore, a chelation step in a conventional sequence prior to a peroxide stage is not necessary. When chlorine compounds are eliminated from pulp bleaching, metal ion content becomes an important consideration (Pye and Lora, 1991).

Basta et al. (1991) reported that a softwood kraft pulp can be bleached to a 70 to 75 percent ISO brightness using the O-Q-P (Q = chelation step) sequence, which they called the Lignox™ Process. These brightness levels can be achieved by washing the pulp after the chelation step and by using high temperatures and long retention times in the peroxide stage.

The Effect of Kappa Number before P on Brightness

The brightness and kappa number obtained after a P_1-stage correlated directly with the kappa number of the pulp prior to the QP treatment (see Fig. 5). Application of QP stages to a pulp at a kappa number of 22 resulted in a brightness of approximately

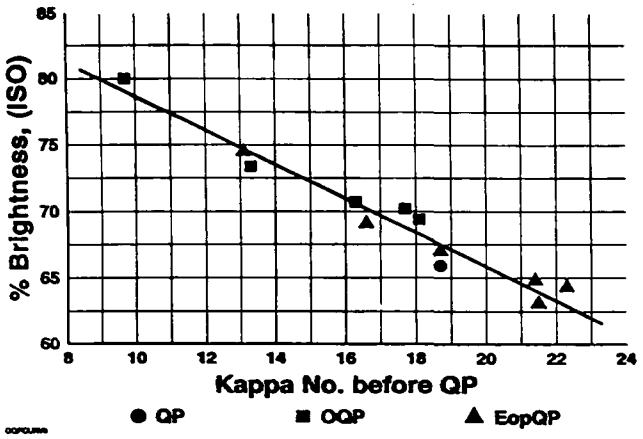

Figure 5.–The tear versus breaking length curve shows no difference in strength in pulps bleached via C_{90}+d_{10}EoDED and O(ZPE)PY.

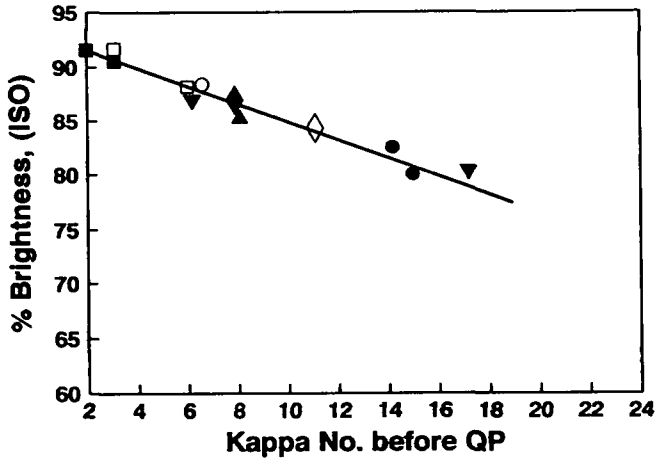

Figure 7.–The kappa number before chelation and perioxide stages as a function of sulfite pulp brightness.

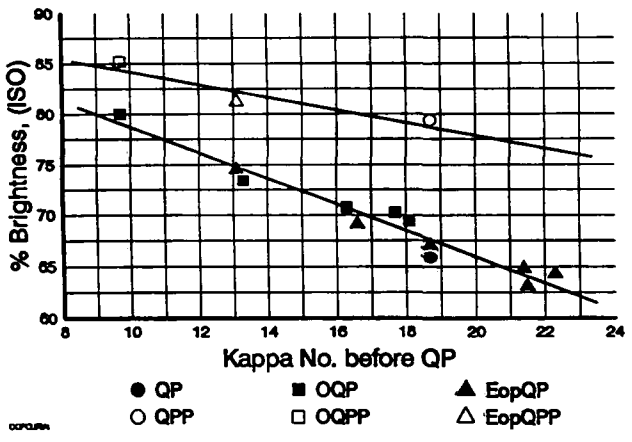

Figure 6.–The effect on brightness of adding a second peroxide stage to a given kappa number.

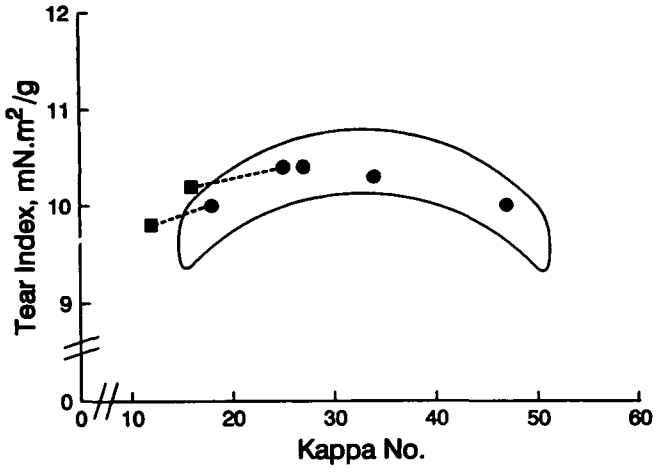

Figure 8.–The effect of low kappa numbers and bleaching processes as a function of pulp strength.

62 percent, but by lowering the kappa number to 10 using a combination of extended cooking and oxygen delignification, the brightness after QP was as high as 80 percent. A kappa number of 16 was required for the peroxide stage to produce a brightness of nearly 70 percent. The method used to lower the kappa number before the QP stage did not affect the brightening capability of the P-stage.

The brightness after QP tended to fall on the same line whether the pulp was conventionally cooked and (EOP)- or O-delignified, or cooked to low kappa numbers without the inclusion of an (EOP) or O delignification stage. A second P-stage (2.5 percent H_2O_2 on pulp) applied to the QP-, OQP- or (EOP)QP-treated pulps increased the brightness by 5 to 13 points (Fig. 6). Figure 7 shows the relationship between brightness and the kappa number for sulfite pulps. Higher brightness can be achieved with a sulfite pulp because of the nature of the lignin.

Pulp Strength

Data on the tear index at 12 km breaking length versus kappa number relationship (see Fig. 8) was supplied by a mill using MCC and oxygen bleaching. Strength depended on the kappa number produced at that time. Oxygen delignification can involve a small loss in pulp strength. If the pulp strength is decreased as the kappa number decreases, further bleaching may result in further strength losses.

The handsheet strength properties of pulps after different bleaching sequences are shown in Table 6. On the spruce pine pulp run Q Eop QP at 70 percent ISO brightness, a substantial decrease in pulp strength properties occurred when magnesium sulfate was erroneously not added to the pulp. The repeat run at 73 percent brightness, with $MgSO_4$ included in the bleaching liquor, showed good strength retention.

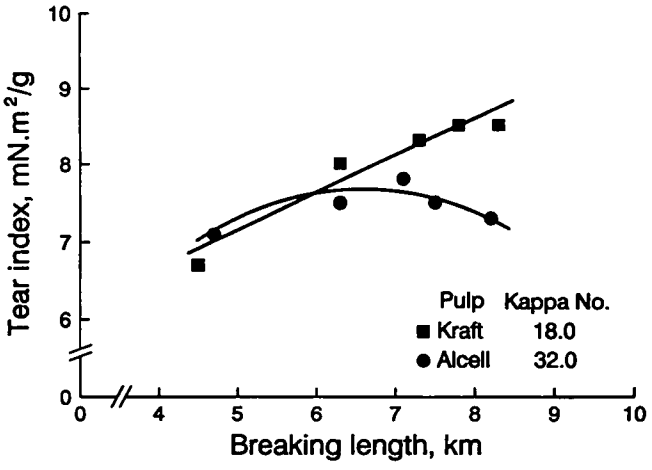

Figure 9.–Curves for tear strength vs. breaking length for a conventionally bleached pulp and an O(ZPE)Y-bleached pulp at 88-90% ISO brightness.

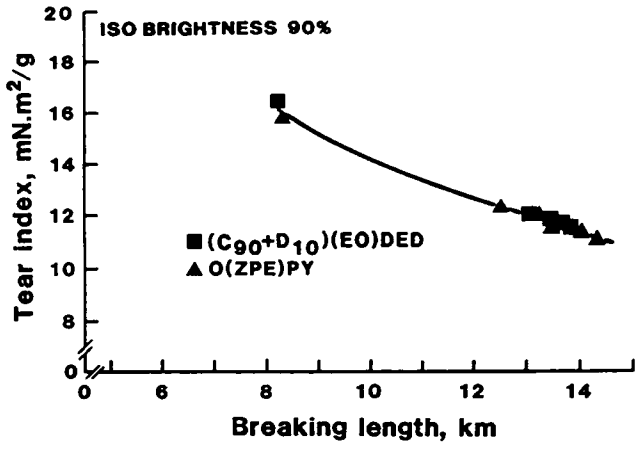

Figure 10.–O(ZE)QP bleaching of Alcell® and kraft hardwood pulps.

Table 6.–Strength properties of pulps

KRAFT PULP			BULK Cm3/g 500*	300	BURST kPa.m2/g 500	300	TEAR MNm2/g 500	300	BREAKING LENGTH km 500	300
White Spruce	CDEoDED	90	1.45	1.35	9.0	9.7	12.0	10.6	10.9	12.0
Londgepole Pine	DEopPDP	89	1.37	1.32	8.60	9.65	11.0	9.5	11.7	12.4
	QEopQPDP	89	1.50	1.32	8.21	8.67	8.4	7.7	10.9	11.2
	QEopQPDP	89	1.51	1.32	8.90	9.7	12.1	10.5	11.2	12.1
Spruce/Pine	D100EopDED	90	1.41	1.35	8.9	9.6	10.4	9.2	10.6	11.9
	QEopQP	70	1.38	1.32	8.6	9.5	9.9	9.5	11.5	12.8
	Q(OP)QP	73	1.39	1.33	8.8	9.7	10.8	9.2	11.6	12.0
	Q(Eop)QPQP	82	1.37	1.34	8.6	9.6	10.0	9.3	11.5	11.9
Mixed Hardwoods	CDEoDED	92	1.51	1.33	4.0	5.9	8.5	8.5	6.7	9.0
	QOQP	85	1.56	1.38	3.2	5.2	7.9	8.4	5.1	8.2
	QEopQPP	85	1.56	1.37	3.8	5.6	8.3	8.4	6.2	8.5

*ml CSF

Bleaching with Ozone

Ozone is capable of delignifying an oxygen-treated pulp to kappa numbers of 5 to 6 (Liebergott, 1972; Liebergott and van Lierop, 1978; Liebergott et al. 1984; LaChenal and Taverdet, 1991; Lindholm, 1991). The conditions, however, must be carefully controlled to prevent cellulose degradation. This factor limits the commercial acceptance of ozone as a lignin-removing agent. Various techniques are being investigated to improve the selectivity of ozone delignification. Pulp properties after O(pZE)PY bleaching to 90 brightness were comparable to CdEoDED bleaching (Fig. 9). Compared to the $OD_{100}EoDED$ bleaching of softwood kraft pulps that is now in commercial use, the OZEoPY sequence produced effluents with about the same BOD, COD, and about 20 percent less color (Liebergott and van Lierop, 1978). Ozone bleaching is being done at the Union Camp mill located in Franklin, Virginia.

Solvent Pulping

Air pollution from kraft mills has reached serious proportions because of the industry's expansion as a whole and because of the tendency to install mills with extremely high pulping capacities. Equipment is available that if properly installed and maintained, is capable of reducing the emission of sulfur compounds from a kraft mill to very low levels. Nevertheless, even using the most effective pollution control systems, there may still be an occasional release of high concentrations of malodors. Any modification of the kraft process would result in reduction of the quantities of methyl mercaptan, dimethyl sulfide, and dimethyl disulfide produced per tonne of pulp would clearly be of great value. The use of a pulping process that does not use sulfur as a chemical in the process should not produce associated malodor. Three types of sulfur-free process have been suggested:

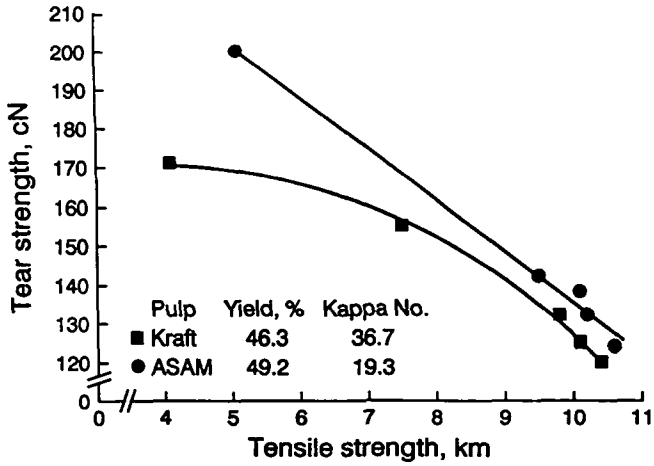

Figure 11.–Bleaching of Spruce Kraft and ASAM pulps.

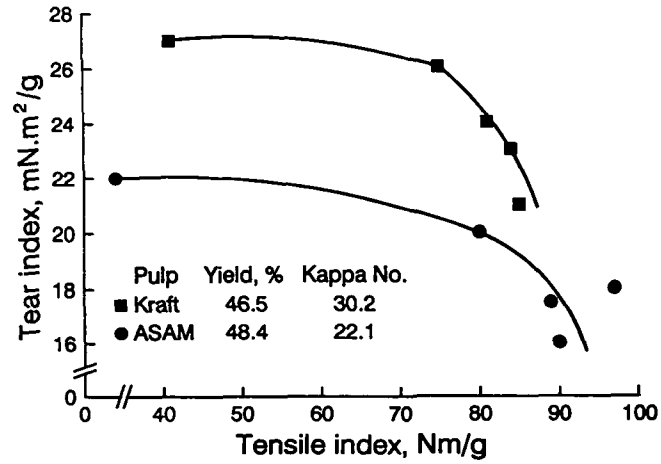

Figure 12.–OZEP bleachng of Douglas Fir Kraft and ASAM pulps.

solvent pulping, soda-oxygen delignification, and oxygen-alkali pulping.

Although solvent pulping was first proposed in 1931, the processes closest to commercialization are Alcell®, Organocell, and the alkaline sulfite-anthraquinone-methanol (ASAM) process.

Alcell® Process

The Alcell® process, now owned by REPAP, Inc. (Pye and Lora, 1991; Cronlund and Powers, 1991), is being pilot tested as a batch system. It uses wash liquor displacement at the end of the pulping period to separate the extracted lignin.

The process uses 60 percent aqueous ethanol for a cooking time of one hour at 195°C and 400 psi in the digester. Plans have been made to expand the plant to 300 tonnes per day, using a continuous digesting process with 50 percent ethanol and a pH of 4 (because of wood acids). Because no catalysts are added in the Alcell® processes, only hardwoods can be effectively pulped.

Alcell® operates a 15-tonnes per day demonstration plant in Newcastle, New Brunswick, Canada, where hardwood solvent brownstock is blended with kraft pulp and bleached for use in lightweight coated paper production.

Oxygen delignification of an Alcell® mixed hardwood pulp (maple or poplar and birch) produced a pulp with a kappa number of 9.9. Ozone treatment increased the brightness to 62 percent (0.5 percent ozone on pulp) and to 79 percent when a 1 percent ozone charge was used. Peroxide treatment produced a final brightness of 89 percent with strength properties comparable to those of a kraft hardwood pulp (see Fig. 10).

Organocell Process

The Organocell process was adapted to include softwoods and can involve the addition of sodium hydroxide and anthraquinone to chips preimpregnated with methanol (Kleinert, 1974; Maston and Granzow, 1982). The caustic must be recovered, of course, and this necessitates some type of causticization or electrolysis. A 5-tonnes per day pilot plant has been operating several years, producing laminate paper grades and trial runs of a variety of other printing, fluff, and tissue papers. Organocell Thyssen GmbH plans to open the first commercial solvent pulp mill (430 tonnes per day) later this year, rebuilding a shutdown sulfite mill in Kelheim, Germany. Spruce will be pulped with temperatures of 165°C with 30 percent methanol in one stage in a specially designed Kamyr, Inc., continuous digester that was erected last summer.

ASAM Process

The Alkaline Sulfite-Anthraquinone-Methanol (ASAM) process was developed in Germany, and a 3-tonnes per day digester pilot plant was installed in April 1990 (Schubert and Fuch, 1992). The process allows high-yield, kraft-type strength, and bright, chlorine-free bleachable pulp. Relatively easy kraft mill conversion is claimed, but no significant savings in capital cost per tonne when causticization is required. Although this process cannot be called sulfur-free, it has certain advantages in pulping. The strength of the bleached ASAM pulp after non-chlorine-compound bleaching is species dependent: spruce pulp responded excellently (see Fig. 11), while a Douglas fir showed some strength loss (Fig. 12).

Conclusion

Considerable strides have been made over the past years to modify the design and operation of bleaching plants to reduce undesirable chemicals in the wastewater discharge. A major thrust has been placed on cutting back on the use of chlorine in the bleaching process.

Work is continuing in many laboratories and pilot plants around the world to evaluate the feasibility of bleaching hardwood and softwood kraft and sulfite pulps without chlorine compounds. It is equally important to gain an understanding of the effects the new pulping and bleaching processes have on the properties of pulp.

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Trade-Off Issues — The Impact of Pollution Prevention Techniques on Paper Products

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At this conference, we have heard many speakers describe a variety of bleaching sequences, both old and new, and their impact on emission loads. I will take us beyond the pulping and bleaching processes to show you some of the implications these new sequences have on productivity and on the quality of the products our industry manufactures.

For the most part I will base this paper on my experience with the pulp and paper grades that my company, Champion International, manufactures in its large integrated kraft mills. The paper grades are referred to as "free-sheet" grades and they are used for making a variety of products used in the office and by consumers. They include the kind of papers you are all familiar with, such as envelopes, bond, tablet, copier paper, and so on. They also include coated papers suitable for use in magazines, such as *National Geographic, Architectural Digest,* and *Mademoiselle.* The pulp brightness required to make these grades is about 85 ISO, and a mix of softwoods and hardwoods is used.

My company also manufactures both soft- and hardwood market kraft pulps, which have a brightness requirement of 90 ISO. These market pulps and the pulps used to manufacture the coated and uncoated paper grades are made by the kraft chemical pulping process and bleached with chlorine and chlorine dioxide.

Before I start discussing trade-offs, let me talk briefly about the driving forces that are causing change in the pulp and paper industry today. Of the two major forces active today, the first one is the customer. The pulp and paper industry is very customer oriented. Some companies sell products directly to consumers while others, such as Champion International, for the most part, sell to companies that add value and make their own final product for sale to their customer. For example, publishers buy our coated paper grades to make magazines, and converters buy the uncoated grades to make envelopes, tablets, or some other final product. I want to emphasize the fact that we don't dictate requirements to our customers. They tell us what they want, and we do our best to fulfill their needs.

Regulation is the other major force driving change in our industry. Environmental regulations, such as those derived from the Clean Air Act and pollution prevention programs, are a focus and an impetus for the research that our industry is carrying out and for changes in process technology and raw materials. Thus, our goal is to provide our customers with the products that they want while fully meeting our environmental obligations. Otherwise, we will not remain economically viable and competitive in an increasingly regulated and global environment.

Distinguishing Paper Uses and Attributes

Paper is an engineered product with a very complex structure. Though we usually think of paper as merely a surface, it is three dimensional, and its thickness (caliper) is extremely important in determining its performance. Simply stated, papermaking involves building structures to perform for very specific end uses. Tissue paper, for example is designed to provide a fair amount of absorbency.

By contrast, paper for magazine publishing is designed quite differently.

The goal for publication papers is to hold the ink on the surface of the paper to enhance good image and color reproduction — what we in the trade call "ink snap." However, a small amount of absorbency is also required to anchor the ink on the paper so that it won't scuff. The sheet is engineered, therefore, to provide a balance between these two competing properties, and its production requires considerable know-how. Copy paper offers another means of reproducing words and images, but its requirements are completely different from those needed for performance on a commercial press. And the requirements for packaging papers are a different story altogether.

Quality is as important in paper products as it is for automobiles or televisions. Whatever we do, we cannot compromise the quality our customers expect of our products. Let me talk about some of the parameters that affect product quality. I will begin with strength, which essentially represents the paper's ability to resist tear. Strength is a function of the fiber species, how they are pulped, bleached and refined, the chemical additives used during the process, and how they are formed on the paper machine. The fact that so many previous speakers have emphasized pulp strength underlines the importance of this property.

First, the level of strength required will vary for different paper grades. Paper is made in a continuous process and a certain amount of strength is necessary for the web to run continuously. If we have too many breaks on a paper machine, productivity is going to decline and with it, profitability. Too many breaks on the paper machine also erode product quality because of the up and down nature of the process in that mode. Essentially, a paper machine is like an assembly line; it needs to run smoothly and steadily. In a highly capital intensive industry, achieving a high level of productivity is a must.

Our customers, the people who use our paper, face the same issue. Let's consider publication papers, which are sold to publishers for printing magazines on high-speed printing presses. The printer also wants a web of paper that runs continuously, without breaks. Too many breaks on the press result in inconsistent quality because the printer is constantly adjusting the printing press, changing roller pressure, changing ink tack, cleaning up the blankets, and so on. The same situation applies to the office environment, where high-speed copiers are expected to produce large numbers of copies without interruption due to paper jams. This issue of productivity and consistency is extremely important to papermakers, printers, and office workers.

Those of us who make copy paper think of copiers and laser printers more as torture chambers than as printing devices. If the paper is not engineered precisely, it may "curl" and jam the machine, particularly in duplex (two-sided) printing. Curl is a scrolling of the sheet of paper caused by dimensional instability brought about by the heat and pressure of the process. A paper jam in a high-speed copy machine is not a pretty sight, and it is not appreciated by office workers and managers responsible for productivity. The trend in copiers and laser printers today is to increase speed and output, and as a result, the demands on paper are also increasing.

The appearance of the paper is another important aspect of product quality. In the pulp and paper industry, appearance is defined by the paper's optical properties and its cleanliness. The optical properties include brightness, opacity, and shade. Cleanliness is most often measured by the absence of dirt specks on the sheet. These specks are undesirable because if they are of a certain size they can have a negative impact on the aesthetics, that is, the "look," of the sheet, or they can be misleading in automatic optical scanning machines. On scanning machines, a speck of dirt can look like a piece of information, a period or a comma, for example. This "reading" can, in turn, lead to serious errors in the printing and subsequent interpretation of certain documents, such as a bank statement or an insurance claims summary.

Our customers do not expect to be slowed down or misled by such imperfections and would not tolerate them for long. Although the lack of optical properties or cleanliness generally does not affect runability on a printing press, the publisher or art director who purchases our paper would be very unhappy if it does not meet requirements. The industry and its customers have developed very specific standards for these properties and our customers expect that we will deliver papers that consistently meet these specifications.

I want to emphasize again that I am speaking from the perspective of a North American manufacturer and supplier, and that I realize that conditions are very different in certain parts of Europe. In North America, our customers tell us that they want environmentally friendly products, but it is very clear that they don't want to give up quality or pay higher prices.

Emissions Control and Trade-offs

Now let's focus again on bleaching chemicals and the different bleaching processes used in our industry, since they contribute a substantial share of the emissions produced by a pulp and paper mill. There are essentially three approaches to reducing emissions: we can reduce the use of existing bleaching chemicals, use different bleaching chemicals, or switch to different bleaching processes.

What trade-offs need to be recognized and made part of this context? First, if we simply reduce the use of conventional bleaching chemicals, the obvious trade-off is low brightness. We have already determined that North America has no real market for low-brightness pulps at this time, and that most customers are not interested in low-brightness pulps even at lower prices.

If we use different bleaching chemicals, for example, chlorine dioxide or hydrogen peroxide, we find that pulp quality can be maintained, albeit at increased cost. The problem or trade-off is that customers are generally unwilling to pay more for a molecular chlorine-free sheet or for one that is made with chlorine dioxide and hydrogen peroxide. In that case, the industry has to absorb the increased cost.

If we look at new bleaching processes, such as the one using ozone, we find that the trade-offs are, in general, lower pulp strength and — even more important — more difficulty in controlling quality. Inconsistent quality can only result, as I mentioned earlier, in lower productivity on the paper machine and rejection by the customer.

Impact of Bleaching Sequences

Let us briefly review the trade-offs associated with some of the bleaching sequences that were previously discussed in this conference. These trade-offs are illustrated in Figures 1 through 5. The data shown in these figures are from commercial processes and experimental evaluations carried out by Champion International and they are in good agreement with the results of similar studies published in the literature. Beginning with a sequence that would have been typical 10 years ago (at the extreme left of the figures), we go on to show the effects of increasing the level of chlorine dioxide substitution (moving left to right); a totally chlorine-free (TCF) sequence; and two experimental sequences in which bleach plant filtrates are recycled to the recovery process.

Increased levels of chlorine dioxide substitution reduce the biochemical oxygen demand (BOD), adsorbable organic halogens (AOX) and color in the plant's emissions. In commercial and laboratory experience, when an increased level of chlorine dioxide substitution is combined with extended delignification, these emissions are further substantially reduced. Please note that all of these sequences still allow the papermaker to achieve the 85 brightness level that is required to manufacture

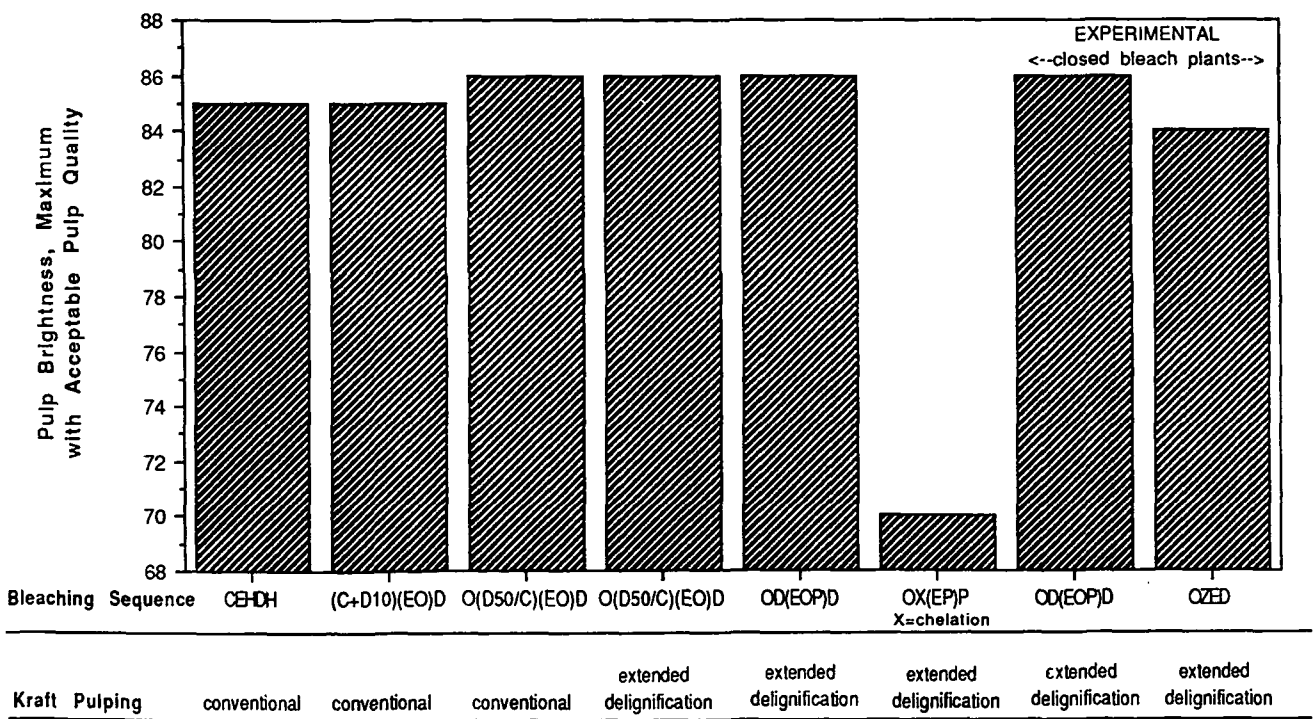


Figure 1.–Maximum Pulp brightness with acceptable pulp quality for various bleaching sequences.

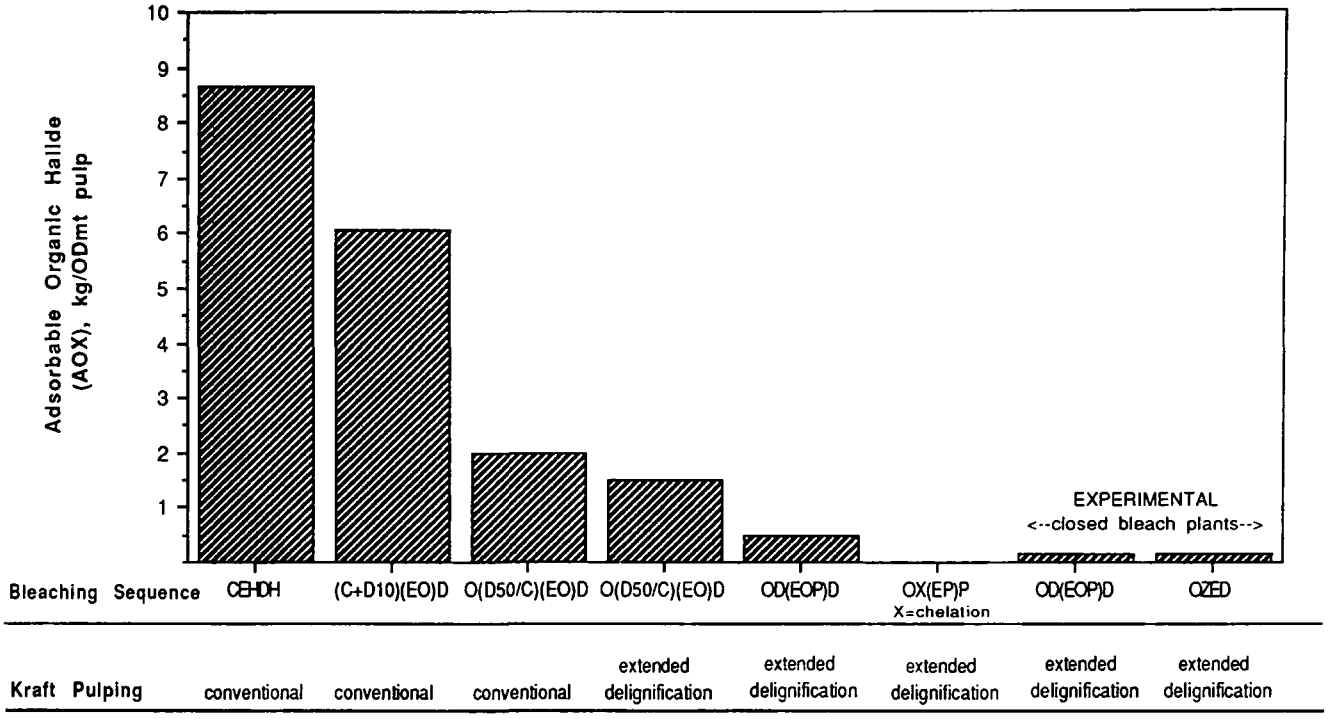


Figure 2.–Reduction in AOX through bleach plant evolution.

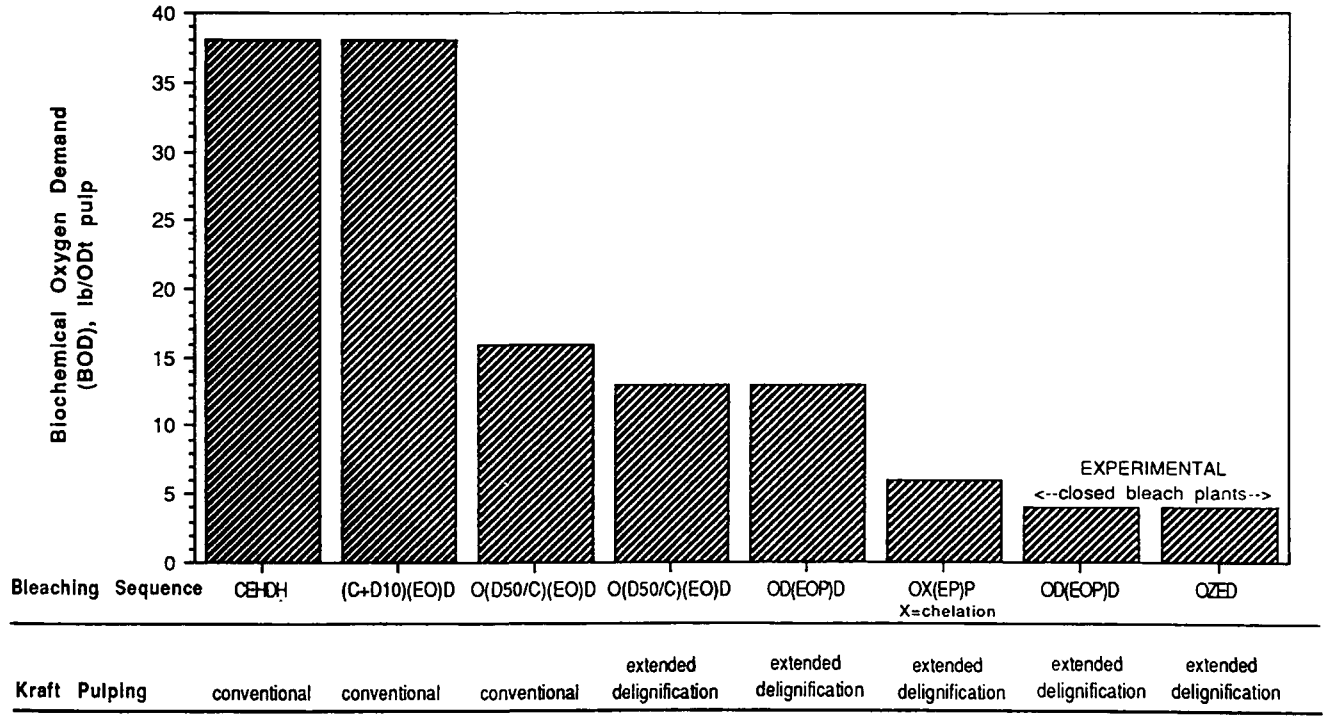


Figure 3.–Reduction in biochemical oxygen demand through bleach plant evolution.

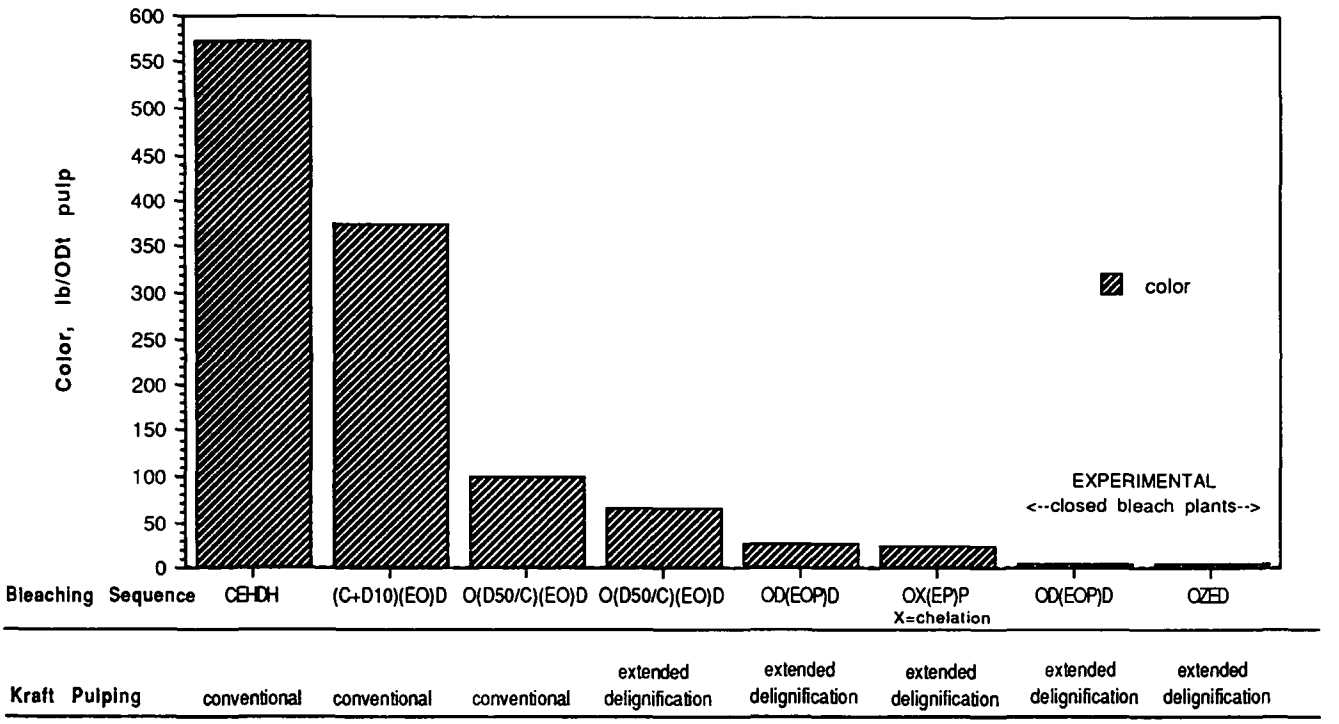
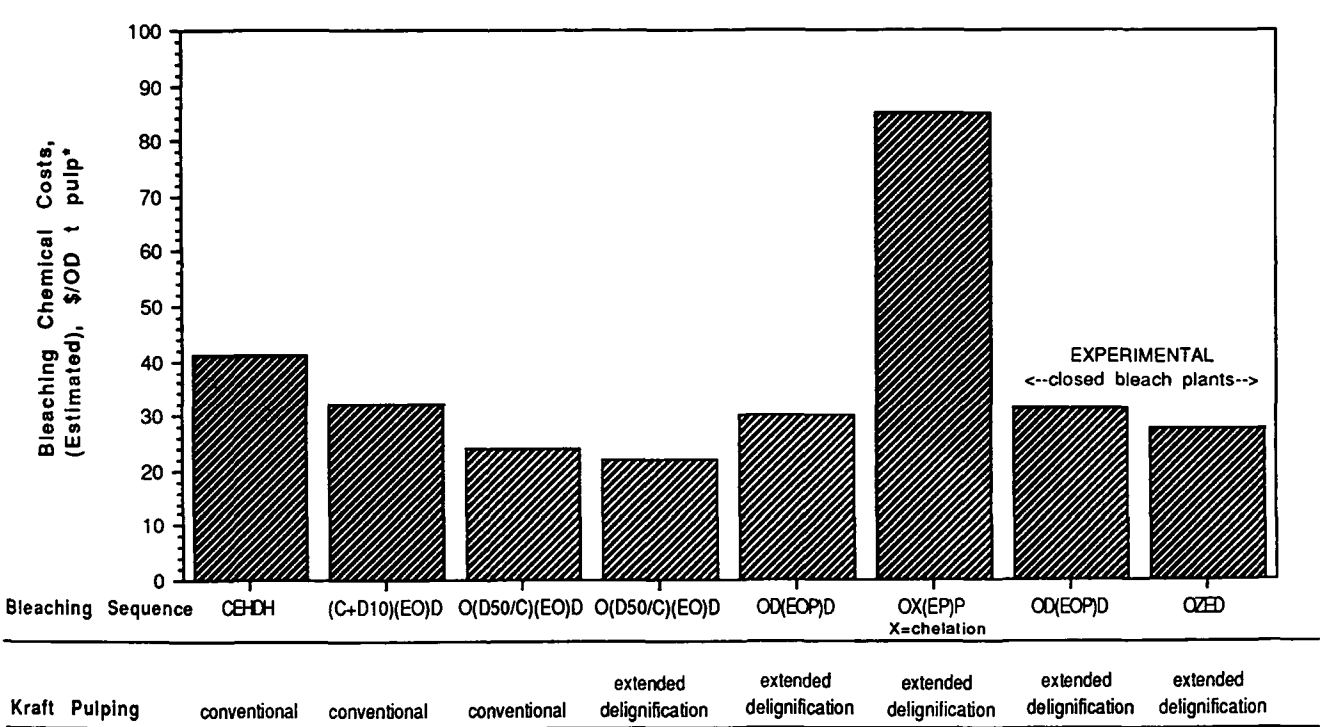


Figure 4.–Reduction in total bleach filtrate color through bleach plant evolution.



* range of estimate +[0.1(cost from figure)]/2

Figure 5.–Estimated bleaching chemical costs for various bleaching sequences.

free-sheet grades of paper. In fact, as we go up in chlorine dioxide level beyond 50 percent, we find that the brightness ceiling actually goes up (see Fig. 1). Experiments with totally chlorine-free sequences, such as OX(EP)P, have yielded low-brightness ceilings, around 70 to 72, but they also further reduce BOD and color and bring AOX to extremely low levels. As indicated in Figure 5, operating costs are higher for some of these sequences, particularly for the totally chlorine-free sequence — there, the costs are more than double.

Let me talk about the two sequences on the extreme right hand side of the figures. These sequences are experimental in that the bleach plant's filtrates are recycled to recovery, and ozone is used as a bleaching chemical in one of them. (The OZED sequence will become commercial with Union Camp's startup of its ozone bleach line at Franklin, Virginia, later this year). The advantage of the OZED sequence is that, with no chlorine compounds in the first three stages, the bleach filtrates can be recycled to the recovery boiler with little fear of corrosion since few chlorides will be in the system.

We believe that there is a great deal of potential in doing the same with the OD(EoP)D sequence. The elimination of molecular chlorine reduces chloride levels, and the use of chlorine dioxide allows us to continue to make an extremely good quality product. Allowing for good research and some time, we believe that we can develop the technology to recycle the bleach filtrates produced by the OD(EoP)D sequence. As shown in Figures 3 and 4, emissions would be equal to those produced by the OZED sequence. The OD(EoP)D sequence also achieves greater color and BOD reductions and approximates the AOX levels of the TCF sequence. According to our projections (Fig. 5), recycling of bleach plant filtrates would not raise operating costs, although the expenditure of capital monies would, of course, be required to install the process.

Conclusion

I have discussed only a few of the trade-offs associated with the new bleaching processes being proposed today. These trade-offs are very real and they directly impact our industry's ability to compete and remain viable on a worldwide scale. We are ready to take on the challenge of developing technologies that will help us meet future environmental regulations while still preserving our economic viability. In the longer term, we realize that we must work toward fuller closure of our mills and the recycling of bleach plant filtrates is a critical first step. TCF bleaching is not the only way to achieve that first step.

A number of initiatives have begun in the industry and in research institutions around the world to investigate the recycling of bleach plant filtrates. The technology is not yet fully developed, but I think it shows great promise. If it becomes a reality, the AOX now present in the effluent from kraft bleach plants could be reduced to extremely small, probably non-detectable, levels. This prospect is an attractive one because the environmental goals of TCF bleaching could be achieved while still preserving the use of our best bleaching chemical, chlorine dioxide. This achievement would, of course, ensure that the industry could continue to deliver quality products to its customers and maintain its long-term competitive posture — which, I hope, is a shared goal of all the people attending this conference.

Unbleached Coated Kraft for Beverage Cartons

Rune Anderson
Director
Frövifors Bruk AB
Frövi, Sweden

Frövifors Bruk AB (FRÖVI) is a rather small pulp and board mill producing about 200,000 metric tons of coated and uncoated paperboard per year. The mill is situated in Frövi, a city in the middle of Sweden in a typical woodland district. The water supply comes from a small river that goes right through the mill. The effluent goes back to that river a few hundred meters downstream just before the river forms a lake. Many vacationers, including our employees, swim in the lake and keep summer houses there.

FRÖVI has produced pulp and paper in the same location since the 1890s. For a long time the primary products were unbleached kraft market pulp and thinner grades of kraft paper. The market for these products gradually deteriorated, and in 1979 the board of directors decided to make a major investment in a large paperboard manufacturing machine, which would also be capable of coating the material. Several related modifications were made to the pulp mill at that time.

As previously noted, FRÖVI's effluent is discharged into a small river. That river feeds into a larger river, which eventually becomes part of the water supply for Stockholm. Because water quality was a concern and because technology was limited in 1979, it was considered impossible to produce bleached pulp. So, partly inspired by some far-seeing U.S. companies, and partly in cooperation with a prospective customer, the mill was set up to produce unbleached coated kraft board, mainly for use in beverage cartons.

Quality Requirements

FRÖVI customers are interested in buying a material with a specific bending resistance that holds print well at the lowest possible weight (and lowest possible cost per square meter). The customer additionally assumes that a number of other important criteria will be met during conversion, transport, and at the product's destination. The criteria include

- physical, chemical, and biological cleanliness;
- manufacturing in accordance with applicable laws and regulations;
- sufficient strength perpendicular to the plane to withstand the strain and stress in printing and polyethylene (PE)-coating;
- resistance to edgewise penetration of some liquids occurring in the filling operation (hot hydrogen peroxide for aseptic packages) or after filling (lactic acid imitating the liquid being filled in the carton); and
- quality consistency within and between board productions.

Pulp and Board Mill Cleanliness

For optimal strength, wood should be processed into pulp having fairly high Kappa numbers (65-70). The problem is to get pulp that is free from physical impurities. Chip quality is important. We try to ensure that by careful debarking, thickness screening (maximum thickness = 8 mm), and presteaming before processing.

After the on-line refining process, the pulp is screened twice; the first is a hole screen (diameter [ø] = 2.0 mm) and the second, a slot screen (slot width = 0.45 mm) (see Fig. 1). The "accepts" from the second screen have a high degree of cleanliness and are used for the outer plies in the board machine.

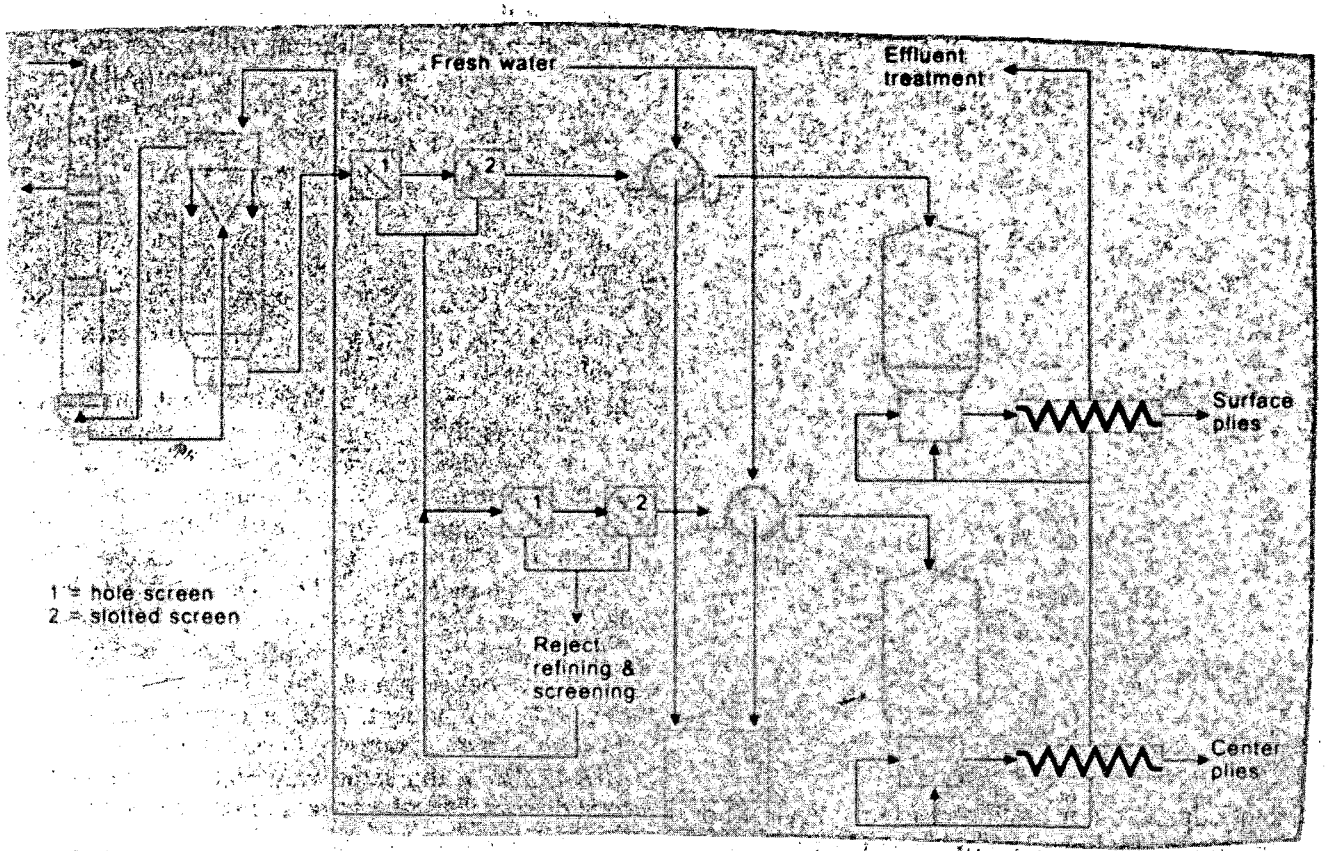


Figure 1.—Pulp supply flow sheet.

The rejects from the primary screens go through a secondary screening, which is basically the same as the primary system (hole ø = 2.0 mm, slot width = 0.40 mm). Secondary rejects are handled in a separate reject system encompassing a thickener, a refiner, and a reject screen. Accepts from the secondary screening are used in the center plies of the board machine.

Chemical purity is vital to avoid off-taste in the packaged liquid. FRÖVI achieves pulp purity through careful pulp washing in four steps using, in order, a digester high heat washer, an atmospheric diffuser, a drum washer, and screw presses.

The wash loss is about 6 kg Na_2SO_4 per ton. After final washing, the dissolved organic material content of the pulp is usualy 4 to 6 kg per ton (as COD). We also believe that it is essential for the wet-end chemistry of the board system to keep the kraft mill water separate from the board mill water. The screw presses (Fig. 2) are excellent for that purpose.

Biological purity is achieved through good working routines. Periodic shutdowns for system cleaning are important parts of such routines. It is also important to check that the design of tanks, chests, and other equipment prevent stagnant zones, where biological activity can thrive.

Board Machine

To meet the quality requirements discussed earlier (see Fig. 2), the board machine and the wet end of the board machine were designed to create the best possible formation of the sheet. The board machine is equipped with four fourdrinier units — a bottom ply, two center plies, and a top ply. Top and bottom plies consist of 100 percent unbleached softwood kraft pulp of high physical cleanliness. The center plies consist of a mixture of unbleached kraft pulp and chemithermomolecular pulp (CTMP). The CTMP is purchased market pulp with extractive content below 0.15 percent. It is used to improve sheet caliper and thus bending stiffness.

The kraft pulps for top, bottom, and center plies are refined separately so that the best conditions for bending stiffness and Z-strength are met. All four plies go through a multistage cleaning to ensure cleanliness. Catalytic decomposition of pulp resin into low molecular, bad-smelling hexanal is avoided by using chelating agents in the stock system.

In our mineral-rich part of Sweden, where the wood has a fairly high content of heavy metals, including manganese, this procedure is particularly important. Each ply has separate dual-sizing systems. Dual-sizing means that a combination of cationized rosin size and AKD is used to obtain suf-

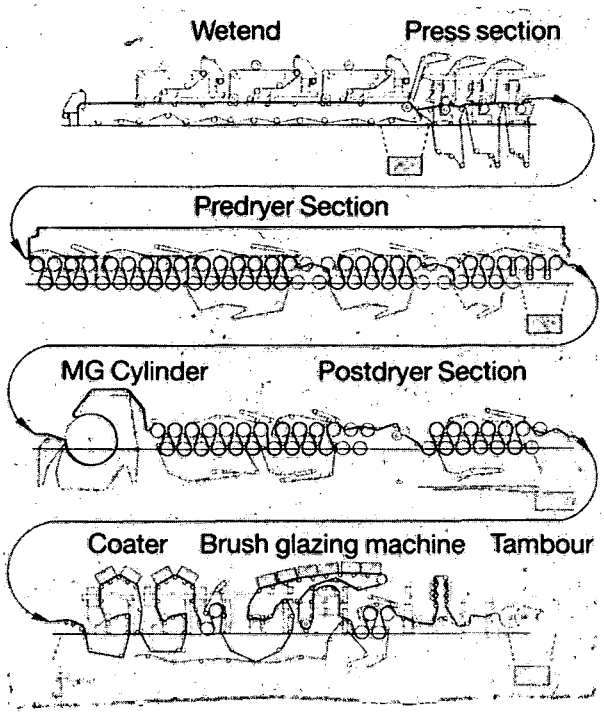


Figure 2.—Board machine.

ficient edgewise penetration resistance against hot concentrated hydrogen peroxide and lactic acid.

Ply-bond strength is obtained by deposit of thin layers of highly refined unbleached pulp on the base wire in two critical positions. Small hydraulic headboxes are used, thereby avoiding the use of spray starch and other materials.

Print-side smoothness is improved by using a Yankee cylinder and a hot calendar prior to the coating sections.

Two blade pre-coaters and an air knife coater in the coating section are used to create even coverage and specified brightness. The reverse side rod unit is used for starch treatment of the back side, mainly to avoid fiber dusting. The coatings are dried by hot air and two infrared treatments.

Environment

As part of our company's environmental policy, we deliberately admit that we as a producer of pulp and paperboard are influencing the environment in a negative way. At the same time we state that it is the responsibility of all company employees to minimize that influence.

FRÖVI has been working actively for more than 20 years to reduce pollution to air and water. In the early 1970s, we installed an aerated lagoon that still operates in a modified state. The important task, however, is not external cleaning but internal efforts of the producing departments to stop contaminating the main effluent. Mill water systems have been contained to a great extent. All major sulfur-containing flue gases are scrubbed, and the recovery boiler and biofuel boiler are continuously monitored. We recently installed a membrane-filtering system for low consistency spills of coating color, to eliminate the risk involved in discarding coated pigments (TiO_2) into a body of water that eventually feeds into the local river (see Fig. 3). The spill, therefore, will be recovered and reused as coating color.

As there is no bleaching in the plant, difficulties with dioxins and other potential carcinogens do no occur. (FRÖVI pulps and water have been analyzed and found negative.) The mill efforts are therefore concentrated on biological and chemical oxygen demand (BOD and COD), sulfur dioxide (SO_2), nitrogen oxide (NO_x), and suspended solids. Table 1 shows today's (1992) emissions together with the limits issued by the Swedish authorities. Figure 4 shows the development since 1986 in BOD_7 discharge to the effluent. BOD is considered to be a more important parameter in our downstream lake than COD. In the same way Figure 5 shows the total discharge of processed sulfur from the mill.

Other environmentally important parameters exist. It has often been claimed that wood resin in the effluent is toxic for fish and lakebottom fauna. For that reason we make yearly investigations of the bottom fauna both in the river close to the mill and at a distance in the lake. All tests indicate more diversified populations of bottom-dwelling plant and animal life.

The fishing has improved significantly. Pike perch is abundant today about 1 kilometer downstream from the mill. Our final goal will be to establish fly-fishing for rainbow trout in the nearby river.

Conclusion

Since the early 1980s, FRÖVI has produced between 500,000 and 1 million tons of unbleached coated paper for the European market. We believe that this product makes a clean, strong, and useful beverage carton that has a minimal negative impact on the environment. Compared to other products, the energy consumption is low. Coated paperboard has been tested a number of times at an authorized research institute that certifies that "the material can be used safely for food packaging. It may stand in direct contact with dry, moist, and fatty foodstuffs." The same kind of unbleached pulp is also used for the production of coffee filters by another company.

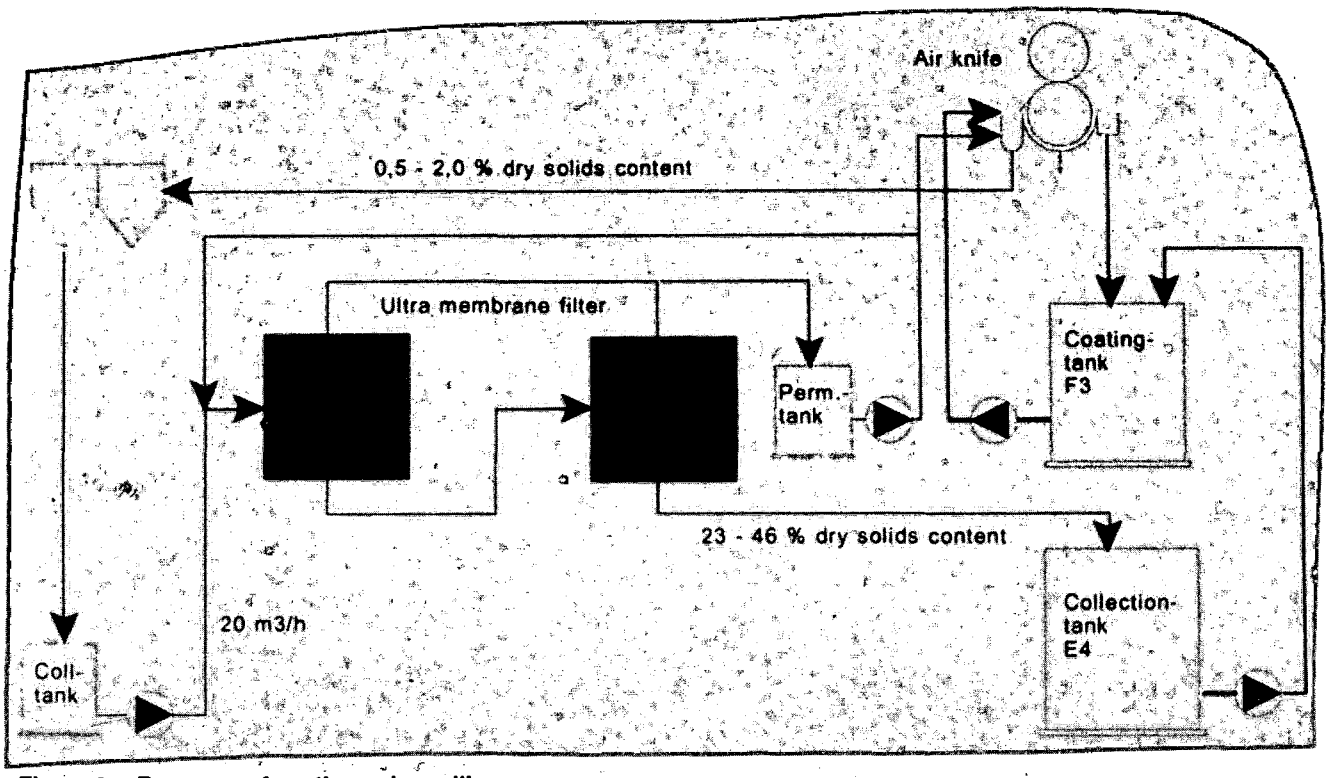


Figure 3.—Recovery of coating color spill.

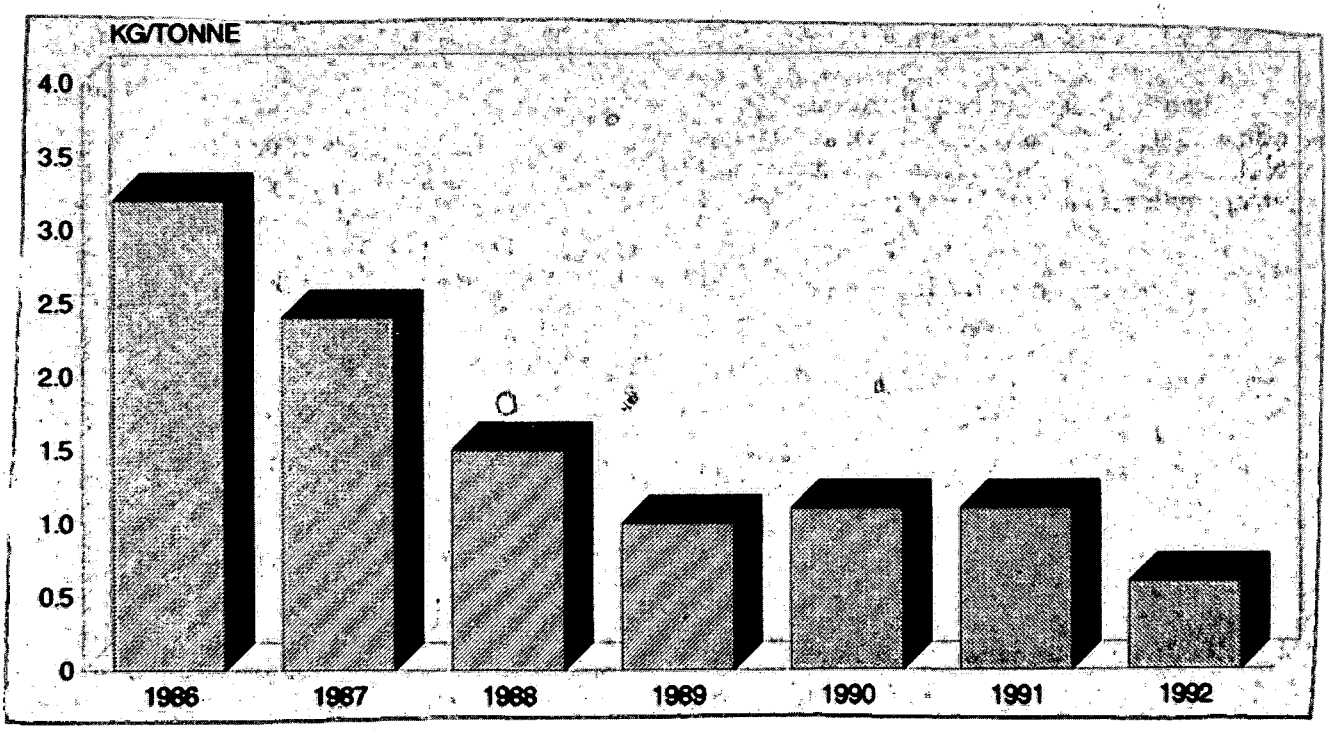


Figure 4.—Discharge of BOD_7, 1986 to June 1992.

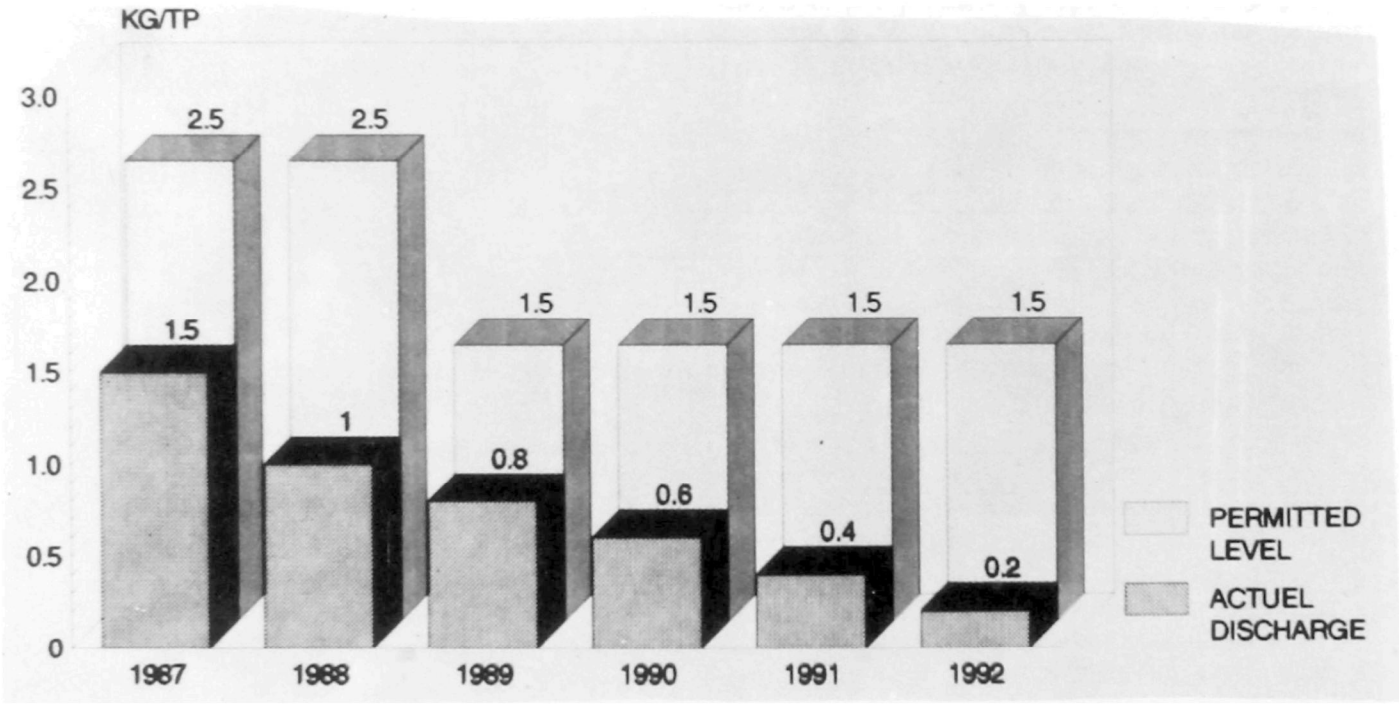


Figure 5.—Discharge of process sulfur, 1987 to June 1992.

The question is thus: Are there any disadvantages? Yes, there are; during prolonged contact with water — in some markets, old-fashioned ice boxes are used for cooling instead of refrigerators — the coating layer underneath the polyethylene is affected and packages can deteriorate, as do other coated products.

The rather thick coating necessary for brightness and good coverage make it difficult to achieve the same bending stiffness yield as the best uncoated duplex grades. Adding disadvantages and advantages together, however, we believe that unbleached coated paperboard definitely has an important position on the market.

Table 1.—Permitted and actual discharge to water and air.

		AVERAGE 1992	LIMIT SET BY THE AUTHORITY
COD	t/d	6.8	9.0
BOD	t/d	0.5	1.2
Susp. solids	kg/d	48.0	200.0
Process—S	kg ptp	0.2	1.5
NOX	kg ptp	2.2	—

Panel 1:
Trade-Off Issues

Question and Answer Session

■ **Jens Folke,** *European Environmental Research Group:* My question is for Rune Anderson. We were told yesterday that ozone bleaching could be the way to a completely closed kraft mill and we were also told that this is far into the future. Now you have an unbleached operation and I would like to hear about the specific loadings from your unbleached pulping operations and about the problems you might have to close up that part of your mill. You also mentioned low energy consumption. I wonder, do you have any figures in terms of gigajoules per ton of product?

■ **Rune Anderson,** *Frövifors Bruk AB:* The figures I mentioned for discharge from the mill are the total discharge. It is not only the board mill but the board and the pulp mill.

■ **Jens Folke:** If you could split these figures and give only the figures for your unbleached pulping operation, do you have any data on that? Maybe in terms of cubic meters per ton of pulp, or maybe in terms of COD coming from the pulping operation?

■ **Rune Anderson:** Not specifically. I am sorry, but the figures you have are from the main effluent off the aerated lagoon. I mentioned a figure for the chemical oxygen demand (COD) of the pulp before it reaches the board mill: that number is 4 to 6 kilos per ton, but it only measures COD.

■ **Jens Folke:** Why is your pulping operation not completely closed?

■ **Rune Anderson:** It is more or less closed. Of course, we have a discharge of waters; the total water consumption in the mill is about 30 cubic meters per ton, of which about 10 to 12 cubic meters are from the board mill.

■ **Jens Folke:** So even though you have an unbleached operation and therefore no theoretical hindrance, you still have to have some outlet from your unbleached operation?

■ **Rune Anderson:** Yes. It is important for the washing efficiency to use a large quantity of water. That may be a disadvantage, but we have to do it.

■ **Jens Folke:** On energy consumption . . do you know how many gigajoules you use per ton of pulp?

■ **Rune Anderson:** In the board mill, the kilowatt-hours used per ton of board are around 600, and the pulp mill uses around 700. The total consumption of electricity is around 1,300 kilowatt-hours per ton.

■ **Jens Folke:** Is the rest of the energy self-supplied from the pulping operation?

■ **Rune Anderson:** Part of this energy is generated inside the mill, and a back press at Arben supplies about half of that energy.

■ **Jens Folke:** So how much comes from external sources?

■ **Rune Anderson:** About half, about 600 to 700 kilowatt-hours per ton.

■ **Med Byrd,** *North Carolina State University:* I direct my question to Dr. Closset. When we talk about trade-offs we often look at the short-term trade-offs to the things that affect us right now, for example, brightness, strength, and customer acceptability. Particularly in your type of products, do we look enough at the long-term trade-offs when we make a fundamental shift in the bleaching

process followed by a fundamental shift in closing up the mill effluents? Couldn't these shifts cause an increased concentration of different ions? Is there a way to estimate or to research the effect that this increase could have on the long-term performance of critical quality papers, for example, on brightness reversion, yellowing, and long-term decomposition?

■ **Gerard Closset,** *Champion International Corporation:* I think that these are precisely the things we should look at very carefully when we begin to use new bleaching sequences. In fact, we try to establish technical alliances with our customers so that we can work with them into the future, to make sure that we have the technology to meet their future needs. When we look at new bleaching technologies, we have in mind the long view. Again, the new bleaching sequences will be commercialized. Our main focus is to ensure that we can continue to make these products — or the products that our customers will require in the future.

■ **Med Byrd:** And you feel that we can accurately simulate the long-term performance of this technology in the laboratory or pilot plant? Do we really have the tools to simulate long-term performances of these changes in the process?

■ **Gerard Closset:** Yes, I think we can go a long way toward establishing the impact of these changes in the laboratory.

■ **Bruce Fleming,** *Boise Cascade:* I have some comments for Norm. I enjoyed your talk, which was packed with useful information, as always. I also enjoyed the baby pictures; they were very clean, with no poo-poo. And it was the same in my talk yesterday: there was no poo-poo in my remarks about ASAM. I want to get that clear. I did not say that ASAM pulp was in any way inferior. In fact, on the contrary, I think it's excellent pulp. So I think possibly that bit of my presentation was misunderstood. I hope it will be clearer in my paper, which should be available today.

■ **Norman Liebergott,** *DuPont Canada, Inc.:* What you said was that for certain species ASAM pulp is very good but for some species it does not turn out as well. One of the species, Douglas Fir, has been used at two meetings to show that pulping by ASAM is not as good as the kraft pulping process. There are many hardwood species and softwood species that do come up to spec, even though some species do not respond.

■ **Bruce Fleming:** Well, there's a paper in the TAPPI journal on Douglas Fir in which the conventional bleaching of that pulp was very good, as good as kraft. I don't know what happened with the ozone bleaching results that you show here. But I think something probably went wrong with the ozone bleaching in that case.

■ **Norman Liebergott:** These are not our results; they were published by the ASAM group.

■ **Bruce Fleming:** But the conventional bleaching of that pulp showed good strength. There's deficit in the ozone bleaching and I'm not sure why that is. But all the data that I've seen on ASAM pulp and our own testing on the sample of pulp obtained from a pilot plant in Germany shows that the pulp is equivalent to kraft in strength whether unbleached or bleached conventionally. In all respects, it looks pretty good and often exceeds kraft strength.

■ **Norman Liebergott:** But I'll say it again. Though many species respond well to ASAM, there are a couple species — they don't know why — that do not respond with the same characteristics as they do in the kraft process.

■ **Said Abubakr,** *University of Wisconsin:* My question concerns the strength properties. Mr. Liebergott, you said in your presentation, based on other people's information, that the strength properties of nonchlorine bleached pulp are a little less than kraft chlorine bleached pulp. My question, are any data in the literature based on the actual operation of these papers in paper machines?

■ **Norman Liebergott:** Very little. We hear that some data are available, but the manufacturers themselves who are making the paper from TCF pulps have some problems. One problem is run ability; they do not seem to run as well on high speed machines. As I mentioned before, handsheet properties are one thing, and handsheet properties sometimes look good, but you will hear about problems in running this pulp. We have adapted to it, but it still has a number of breaks and things.

These problems make us think about what will happen in the future when these pulps are finally recycled. Recycled pulps are going to be even weaker. So if the pulp is weaker (than kraft) to start off with, how much can it contribute to recycled pulp strength and how much more aversion fiber are we going to have to put in to strengthen those pulps? Remember back to the groundwood days, when we had to have a certain amount of sulphite or bleached kraft pulp in order to get the pulps to run on the machine. I think we have a lot to learn, and that we're still new in this game. So, if people say the answer to pollution is TCF, that's just not a

complete answer. More research is needed and should be done, not only in the lab but also on machine runs to see exactly how these papers perform.

■ **Susan Cohen,** *Environmental Defense Fund:* A question for Mr. Anderson. Can you tell us when your product was developed, how long it took, what kind of customer demand compelled you to make the change, and what the product looks like?

■ **Rune Anderson:** We started the machine in mid-1981 and the first commercial deliveries of the product I am referring to began in 1982. The product development took about half a year. We have one big customer, Tetra Pak, who is present here tonight.

■ **Susan Cohen:** And was it a dioxin problem that moved this product?

■ **Rune Anderson:** That was always a problem with the liquid packaging board. But we had no bigger problems with that particular grade than with other grades.

■ **Ray Chalk,** *World Bank:* I would like to pursue that same question. In all my many trips to Sweden, I see milk and fruit juice and other consumer products packaged in bleached boards. Are you using this unbleached board at all in Sweden to package things like milk?

■ **Rune Anderson:** I think most of the milk in Sweden is packed in what we call brick packages, which are the Tetra Pak line of packages. Products packaged in unbleached cardboard in Sweden have additional costs. Normal square packages are also used in Sweden. They are duplex board, mostly uncoated.

■ **Jessica Landman,** *Natural Resources Defense Council:* Does your packaging look different to the consumer's eye from the packaging made with bleached board?

■ **Rune Anderson:** No, I don't think so.

■ **Norman Liebergott:** Can you put lost kids on your packages too?

■ **Rune Anderson:** The board is printed in flexographic rotogravure.

■ **Jim Foster,** *Westvaco Corporation:* Given that the value of brown fiber is less than white pulp, could you, Mr. Anderson, comment on the economics of the recyclability of the liquid packaging based on an unbleached fiber?

■ **Rune Anderson:** No.

■ **Norman Liebergott:** You know very well that recycling mills can handle a certain amount of ledger, pure ledger or color ledger. They can also handle a certain amount of wood fiber. But the moment unbleached fiber comes into the mill, it's a problem because it leaves specks. At this point, you have to go into all kinds of things, oxygen and other chemicals, to attempt to handle those specks. Imagine having a large amount of fiber like that; you'll probably have to come up with a completely different recycling scheme.

Paper Specifications and Pollution Prevention — An Industry View

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Vice President, Paper Group
American Paper Institute
New York, New York

I do not know who was responsible for the reception last night. It was unique, I thought, to see so many interest groups talking with one another and exchanging warm fuzzies. Indeed, the euphoria made me very weak. I even promised Margaret Rainey that if I had time left from my talk this morning, she could have it. And I promised her I would be very much to the point. She promised me the same thing and we agreed to disagree, which I think is good because we can do that on an intellectual basis.

The Pollution Prevention Hierarchy

I will begin my presentation with a common hierarchy of approaches to solid waste management, but do not be too concerned: I am not going to talk about landfills. I am not going to talk about solid wastes in the way that we do generally, but I would like to discuss the recycling issue as it pertains to our industry. The paper specifications that concern us are physical and optical properties. We are in fact preventing pollution through new processes, and I will use the recycling area as one example of pollution prevention that we clearly understand and can identify with. Obviously, recycling, waste to energy, composting, landfilling, and market-based source reductions are all parts of the hierarchy.

But the process involved here goes to a question that was raised yesterday: What is the industry spending to help "prevent pollution" rather than simply "contain" it at the end of the pipe? Clearly, recycling alone is not going to prevent pollution, and our industry must not stop there. A comprehensive approach is needed and new processes that will in fact reduce pollution rather than depend on secondary treatment and "end-of-pipe" approaches. Yesterday we noted the significant increase in the production of paperboard and pulp. Today, I ask you to note the tremendous drop in purchased energy. Other processes are reducing pollution — not just scrubbers and other types of things, but at the source. That is a very important point. The American paper industry (in the United States) is taking a proactive approach to become part of the overall solution. Pollution prevention is a key to the municipal solid waste problem, and the entire industry is demonstrating our commitment to pollution prevention leadership, which we believe begins with special efforts in the recycling area.

The first result of pollution prevention planning was the establishment of the goal: a 40 percent recycling of our product by 1995; that is, 40 percent of all paper consumed in the United States will be recovered for domestic use or export by 1995. I think the goal is even more striking since over 50 percent of the newsprint consumed in this country comes, in fact, from Canada, and we are going to recover 40 percent of that as well. In doing so, we have made a public commitment that we can expand and use. The goal has become the centerpiece of our solid waste program, and it has in fact earned us good will and credibility.

Paper Types and End Uses

To further demonstrate the industry's commitment and show what we can do, I'd like to look at some of the paper grades that the Federal government buys — and not just the government but also the public. Since this is a U.S. Environmental Protection Agency conference, I am using government figures and some anecdotal information to show the capital commitments for new expansion and for

added capacity and retrofits that will help reduce pollution. Then we will break these down in terms of specifications, and what is, we hope, intended for the customers.

First, let's look at newsprint. Between now and 1994, newsprint production will consume more than 1 million additional tons per year of recovered newspapers and magazines. Second, let's look at printing and writing paper with its overall capacity expansion rate of 2.7 percent per year. The use of recovered paper in that particular grade will increase 32 percent by 1994, mostly in deinking grades. Third, three of five planned new tissue machines will use recovered paper exclusively. These machines use new processes and technology that goes to the very source of what this conference is about. They help reduce and prevent pollution. Fourth, consider container board. We expect recovered paper in this area to grow at approximately 8 percent per year —nearly five times faster than the projected overall growth for container board, which is projected at 1.7 percent per year.

Our investment, our use of capital, is unprecedented. Over 101 publicly announced projects will be capitalized between 1990 and 1995. In that area alone, on the question whether the industry can put a price on its spending for pollution abatement, the answer is no. We can't. One of the reasons is that capacity growth depends on modern processes, and these processes, in fact, reduce pollution. We are preventing pollution in each new investment and these total capital costs are part of the overall cost of reducing pollution. The industry should be credited accordingly.

Recycling is driven by two forces. Number one, it is driven by public policy, government policy, and expectations. It is also driven by the product's end use. Remember I said, or I meant to say, that I wanted to speak about the policy role first. Now let me add that demand for specific paper grades should, in fact, be based on the function that customers expect a particular piece of paper or paperboard to perform.

Understanding Paper Specifications

Each type of paper is unique. There are different grades. They possess different physical and optical properties that allow them to meet an extraordinarily wide variety of functions. It may be simplistic to say, but I think we need to come back to the basics. And it is basic to say that for your informed purchase of paper, we acknowledge that paper is not just paper. Buying paper just because it is "recycled" or "chlorine-free" ignores the fact that there are certain physical and optical properties required for the function or the end use that the paper will be used to accomplish. One of my colleagues, Dr. Ron Slinn of API puts it this way, and I would like to give some examples of how this notion fits.

In its most common form, paper is seen as thin sheets that carry messages. These sheets are newsprint, printing and writing papers, and office papers. Then we have tissue and toweling papers for use in several other sanitary and hygienic applications, and the tough, flexible papers used in shopping bags and wrapping papers. The porosity of some papers makes them ideal filters in both air and liquid applications, transportation, medical, and many other applications. And, finally, we distinguish paperboard from paper in generic terms only by its thickness — if it's more than 12-thousandths of an inch, we look at it as paperboard. Its stiffness, folding ability, flexibility, and comparative lightness make it ideal for food packaging.

Paperboard also makes a variety of shipping containers coated with resins, wax, or plastic. It is often the principal component of liquid and microwaveable containers as well as water resistant protective sheeting. Paper also forms many specialty products. Paper can range from disposable surgical gowns and hospital bedding to installation for electrical wiring and printed circuits.

Then, when we talk about blends, we are talking combinations or composites with other materials. We find paper blends in laminates for furniture, multiwall sacks, and food packaging with foil. This litany of anecdotal data serves, I hope, to drive home a very basic point. Purchasers of paper should first determine the physical and optical properties required to fulfill the function they have in mind. Some paper and paperboard products perform better if they are whiter and brighter. But the products themselves are not bleached to reach this characteristic. It is of course, the pulps from which paper and paperboard are made that are bleached. And as I mentioned earlier, a whiter and brighter surface can improve the performance of a paperboard product with contrast for legibility. That quality is very important in printing and writing papers and in magazine advertising, where visual clarity and high appeal are critical. These products, I must say, are market driven.

How many of us are over 45? I have 20-20 vision and an eye problem called astigmatism. At night, if there is not a good contrast between the print and paper, or if I am in an area that is not well lighted, I can't read. That is the practical reason for insisting on contrast. Now, let's talk about addressing your needs and the progress the industry is

making. We are beginning to have a knowledge of paper and to move from lack of understanding to one of positive differentiation. The objective is to gain fair treatment of the specifications of unique papers. You should know that there are reasons for brightness, strength, and opacity. But what is the reason for totally chlorine-free papers? Is there a practical reason? That is what you need to know when you are talking and working with changing paper specifications. As an industry, we endeavor to know what those specifications are, and what your demands are, and we are going to meet your needs if they are technically and economically feasible, if they do not risk the loss of paper's physical and optical properties, and if we can do it in an environmentally safe way.

The Paper Industry's Commitment

Our use rate (see Fig. 1) shows the industry's commitment to recycling even during a recession. Despite a general production slow down, the curve increases. However, I have another message for you as well, which is time. It takes time for this industry to change and move. Take, for example, the typical schedule behind the supply of and demand for recovered paper in Figure 2. Notice how fast we can turn on collection systems to get paper. Notice how much longer it takes to get a machine or other facilities in place to use this recovered paper. This time lag affects the whole process of the paper industry. We need time.

We are in fact moving. We are in fact committed to the increased use of recovered paper, and we are way ahead on this score (see Fig. 3). The 40 percent goal is going to be met, but it won't be easy. You can help the paper industry to determine legitimately what is needed, why it is needed, and then create a booming demand for the papers you have identified based on actual need.

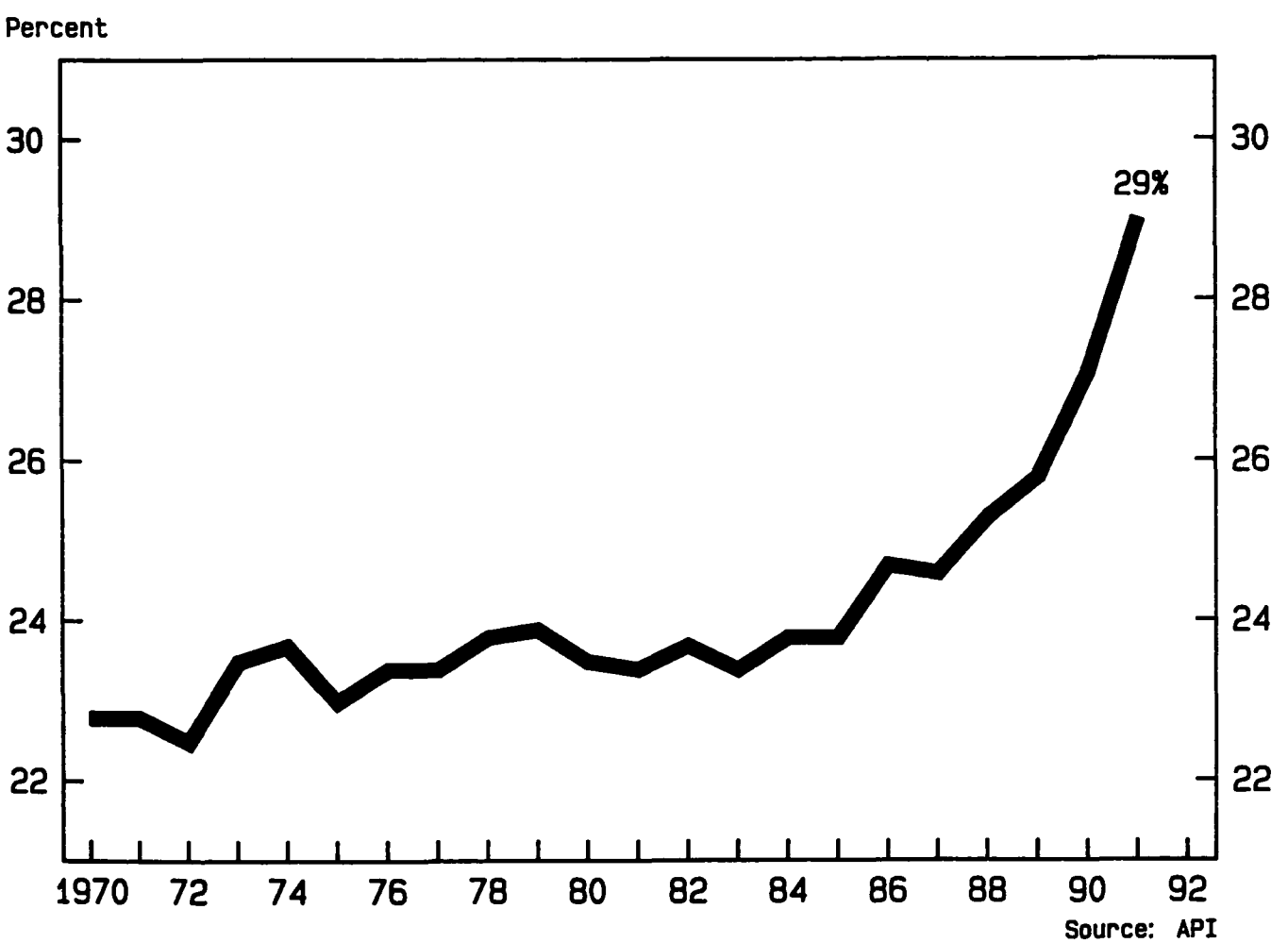

Figure 1.—Recovered Paper Use in the United States.

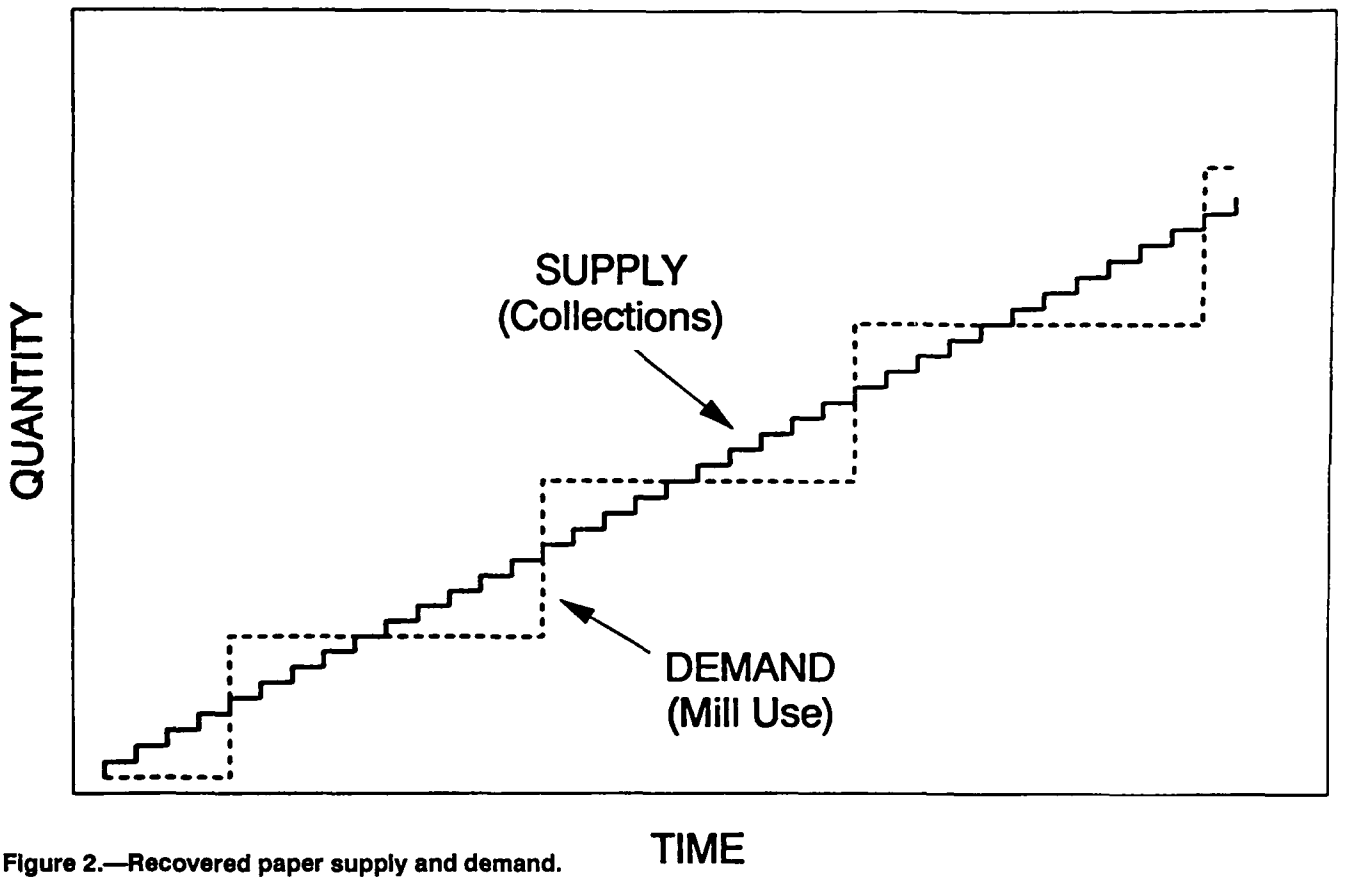

Figure 2.—Recovered paper supply and demand.

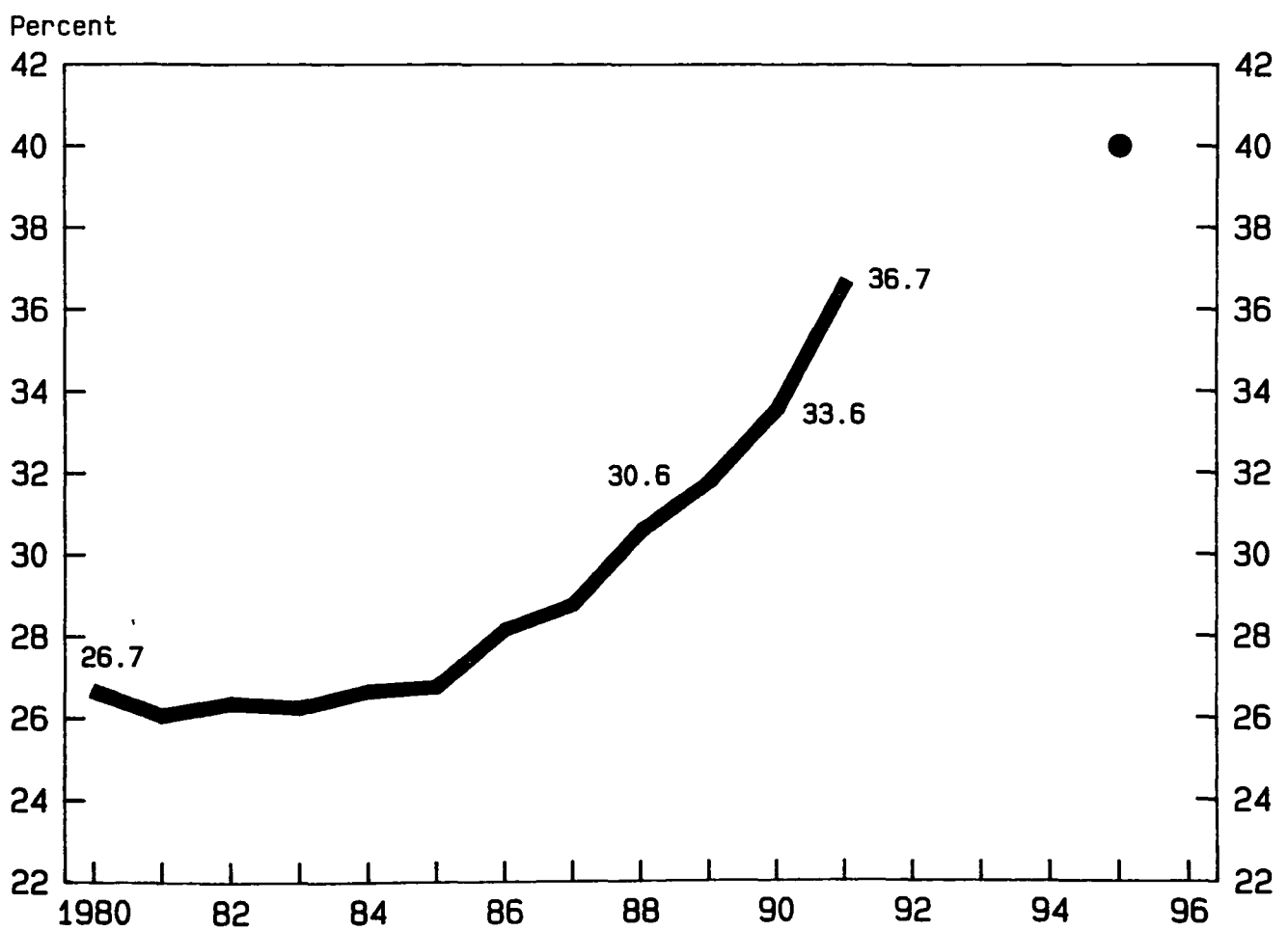

Figure 3.—Paper recovery in the United States.

Opportunities and Barriers for Using Chlorine-free Paper in North America

Howard Sproull III
President
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For more than two years, Eco Paper Source has marketed totally chlorine-free (TCF) paper to a wide audience, gaining in the process considerable insight into the opportunities and barriers surrounding the acceptance of these papers. This paper highlights factors that either restrict or accelerate interest in and use of chlorine-free paper.

Chlorine-free paper can be characterized as an intellectual choice. The technical issues behind the choice require thoughtful consideration. In general, the choice is not for those who are settled in a path of conformity, but for those who earnestly seek out, demand, and welcome meaningful environmental solutions.

Benefits of Chlorine-free Paper

The main factors affecting the use of chlorine-free paper are cost, availability, performance, education, and perception. No restrictions or penalties apply to availability and cost.

Availability is a function of landed inventory and mill capacity. The capacity to produce chlorine-free paper in grades that Eco Paper Source markets already exceeds 1 million tons per year. When landed inventory is insufficient to cover a given project, a direct mill shipment is convenient and easily attained. Direct mill shipments take four to seven weeks — a normal and reasonable time frame.

Nor is cost a barrier. It is usually the catalyst. If we can save the client money, or if our papers are similar in cost to equivalent products, we'll get the order.

Chlorine-free paper performs well in press runs, according to printers. I hasten to add that when asking a printer for an opinion, a positive response usually means a lack of negatives. Yet, with chlorine-free paper, the printers are eager to rave about how clean the sheet runs; how quickly they reach color targets; and how quickly they are able to get press sheets approved by the print buyer.

So the good news is that people who want to use chlorine-free paper need only ask for it. There is no pricing penalty, no sacrifice in quality, and no resistance from the printer. That chlorine-free papers are a meaningful environmental alternative makes them an optimal choice.

Obstacles to Chlorine-free Paper Use

The key barriers to acceptance of chlorine-free paper are education and perception. The chlorine-free choice requires an audience willing to concentrate on a new subject matter that is relatively complex. It requires study to understand the impact of chlorine on the environment during the last 75 years of paper production and the difference between inorganic and organic forms of chlorine. Chlorine-free paper is a choice that requires an audience willing and able to learn.

Why, then, do people accept or reject chlorine-free paper? Why do they print or choose not to print on environmentally benign paper whose production yields health and safety benefits that are compelling, tangible, and meaningful? The answer is perception. It is one thing to provide information and education. Action results from perception.

Perception involves the following questions. Is chlorine-free paper a truly environmental product? If so, can my client understand the issue? If the answer to these questions is yes, then this customer will use chlorine-free paper. Since 1989, I have made hundreds of presentations and thousands of telephone calls. I've mailed literature, samples, and information to thousands of people, including corporate end users, printers, designers, paper merchants, and advertising agencies.

The degree of interest generated by these contacts is directly related to perception. I am pleased to report that a vibrant, actively interested segment of this population now insists on using chlorine-free paper. Why does this group select chlorine-free paper? They understand the issue. These consumers can be characterized as proactive and quality-conscious. They have accepted the challenge of seeking out the best available environmental choices, and they have concluded that chlorine-free paper is the meaningful course to follow.

These individuals are equally concerned with performance. Their research and experience has shown that recycled paper doesn't deliver all the results they want. They know that postconsumer content is the only true measure of recycling's environmental impact.

Paper grades suitable for printing that also have high levels of postconsumer content (50 percent or more) are a very small portion of certain paper classes. They are currently priced at a premium compared to papers with less postconsumer content, and they also exhibit greater resistance to normal press speeds.

Cost, Performance, and Availability

Cost is not a problem. As mentioned earlier, the cost of chlorine-free paper has in all cases been less or equivalent to competing papers. In my opinion, surveys that say people are willing to pay more for environmental substitutes are not accurate. They make good newspaper copy and nice 45-second radio spots, but if you stand in the checkout line, call on a printer, or talk with a designer or a nonprofit group, the important factor is lower paper cost. Again, across the board, Eco Paper Source sells chlorine-free paper at a cost that saves or meets the client's budget.

Performance includes many elements, but its definition here is tied to the following question. Does chlorine-free paper present any significant performance difference to the grade for which it is substituted? The answer is twofold. No significant difference is noted if the substitute is a virgin fiber chlorine-bleached paper, and a significant difference is noted if the substitute has a recycled component. Quality suffers as postconsumer content increases. The chlorine-free sheet runs cleaner, which means a happy press crew.

The chlorine-free sheet reproduces the dot with greater consistency, which means sharper images and screens. The chlorine-free sheet is uniform, which means mottle-free solids. When a printer tries to print a high quality, multiple unit, process-and-match color job on a recycled sheet, he is trying to make a silk purse out of a sow's ear. When printers run a chlorine-free sheet, they have nothing special to watch for — no special inks, no special settings, no adjustment to production speed, no headaches. No performance barriers exist when using chlorine-free paper.

Chlorine-free paper is plentiful and easily attained by those who want it. Eco Paper Source has satisfied virtually all inquiries with a chlorine-free offering. Our chlorine-free papers are appropriate for all types of corporate literature and office use.

Education and Perception

Education has proven to be a significant obstacle. People are slow to act positively on what they have learned. The issues of dioxin contamination, organochlorine poisoning, toxic waste, and the chemistry of chlorinated aromatics are difficult to simplify. Exposing people to these facts causes some discomfort. They may begin to realize the significance of the issue but later find it easy to ignore.

Damage control measures taken by mill representatives who call on the same groups compound this loss of retention and interest by suggesting that the whole chlorine issue is a nonissue. Thus, the educational process becomes a formidable obstacle. There are, however, individuals who seek out information about the issue and having done so, eagerly embrace the chlorine-free substitute.

Perception is a complex obstacle to acceptance and use of chlorine-free paper. People and organizations shroud themselves in environmental images. Environmental image-making perception management are an important marketing agenda. A bandwagon phenomenon can occur. The effect of this phenomenon, however, is a confining one. The parade has room only for one band; additional performers are excluded. This phenomenon is characterized by statements such as "We only use recycled paper," or "If it is not recycled, our audience will not get it, so we don't want to rock the boat," or "People can relate to a landfill, I don't think they care about what disappears into the water and air," or "Who else is using this paper?"

When questioned further, many will admit that the recycled paper they use has minimal or in fact no postconsumer content, but since they can get an "environmentally friendly" logo on it, it really doesn't matter. What matters is the convenience of using something that delivers the image, although it has only nominal substance. As a result, many communication professionals use popular symbols to "greenwash" audiences. Nevertheless, a vibrant, active user's group does exist and does stand out as a standard-bearer for the environmentally safe alternative. As an issue of health and safety, the chlorine-free choice is one that can be highly satisfying! It requires no compromises and sends an appropriate environmental message.

The Original U.S. Chlorine-free Paper Producer Looks Ahead

Archie Beaton
Specialty Paper Sales
Lyons Falls Pulp & Paper
Crystal Lake, Illinois

For those of you not familiar with Lyons Falls Pulp & Paper, I represent the original and only chlorine-free producer of uncoated free sheets in North America. We are a very small, integrated mill, producing roughly 80,000 tons per year. The need in today's market is to specialize — to produce specific products for specific markets. At Lyons Falls Pulp & Paper, we work to meet the current needs of a varied market looking for chlorine-free paper products.

Our production capabilities range from tree harvesting to the production of hydrogen peroxide bleached pulp and uncoated free sheet grades — a range that allows us to produce chlorine-free products for many markets. These markets include the publishers of books, magazines, and newsletters; food packagers; manufacturers of personal care products; manufacturing and service corporations; environmental groups; and universities.

The market is enormous for any paper application open to using a chlorine-free product. As for the issues surrounding chlorine in the pulping process versus products produced without chlorine, we should draw a line in the sand. Companies producing chlorine-free products are not a threat to the paper industry, though it may certainly have signaled a trend for the chlorine industry.

According to the July-August 1992 issue of *Chemical Business*, "Chlorine is fading from the paper scene":

> *The reason for the decline is concern about hazardous chlorine compounds that may be left in the paper or in the process waste stream. As much as 10 percent of the bleach applied may form lignin-derived chlorinated organics that end in the plant effluent, with traces sometimes in the paper. Dioxin is one of these chlorinated organics and, while its toxicity is still intensely debated, dioxin is undesirable by any standard.*

Concerning this substance, the U.S. Environmental Protection Agency (EPA) says that "all U.S. residents now have dioxin in their body tissues in amounts averaging seven parts per quadrillion" (Magner, 1992); and the U.S. Food and Drug Administration says that sport fish have the highest amounts, but traces of dioxin also get into food that is stored or cooked in chlorine-bleached paper.

Many presenters at this conference have discussed eliminating dioxin from pulp and paper products. We seem to be heading in the right direction. As the pioneers of recycling products developed a value-added market for recycled papers, so we appear to be creating a market for chlorine-free products. This market shares its dividend with the environment and the industry through cost savings in chemicals and less environmental impact.

EPA Special Assistant to the Administrator of Water Mark Luttner has noted that he is "not aware of any environmental problems with hydrogen peroxide" (Dutton, 1992). Other studies are more definitive: "Hydrogen peroxide breaks down into hydrogen and oxygen, making it possibly the most environmentally benign chemical used by the pulp and paper industry" (Armstrong and Scott). No dioxins, no furans, no organochlorines, no chlorine gas or other costly pollutants to clean up!

The documentation of advantages can be found in the European market, which has made great strides in producing a wide variety of chlorine-free products, from tissues and fine writing paper to tampons and coffee and tea filters. The

makers of chlorine-free products continue to expand their product line and update their processes. Chlorine-free bleaching is now the preferred process in Europe. U.S. producers are not only lagging behind the Scandinavians and Germans; they are also behind the Canadians.

The Howe Sound Story and Its Effects

A 1990 Canadian Broadcasting Company production, "Howe Sound: Poisoned Waters," dramatized the problem:

> *Howe Sound, just north of Vancouver, is at the center of an environmental battle. Toxic chemicals from two pulp mills have contaminated the inlet, forcing a halt to fishing and shellfish harvesting there.*

This story featured two pulp mills located on a small, beautiful inlet. On a wider scale, it disclosed how environmental groups are trying to force government and industry to account for their actions. The fight being waged at Howe Sound over pulp mill pollution is starting to be fought elsewhere in Canada and the United States.

A story with the same implications is happening today on the Fenholloway River in Florida, the Pascagoula River in Mississippi, the Noches River in Texas, the Androskogen River in Maine, and on the shores of Lake Michigan, among other places.

Today one of the pulp mills in Howe Sound has joined the ranks of pulp makers who produce totally chlorine-free (TCF) kraft pulp. This mill is using hydrogen peroxide to attain a General Electic (G.E) standard brightness of 72 to 80. The pulp will be sold to German customers for a variety of products. In the United States, everyone is constantly talking about brightness: "The numbers are 86 to 90"; "our top numbers are 77 to 78." In many situations those numbers are beyond what's really needed.

For example, we made some paper this year for a reply card user. The company's agency got printed samples containing 100 percent coverage. The agency rejected our 74. When we discussed the cost savings and pulp retention issues with the end user, however, they overrode the agency, preferring less brightness.

In British Columbia, regulators want all adsorbable organic halogens (AOX) out of all pulp effluent by 2002. In effect, these rules will force pulp producers to stop using chlorine and chlorine compounds in the bleaching process. British Columbia's Environment, Lands, and Parks Minister, John Cashore, recently acknowledged that pulp producers "have already made significant improvements, as have many of our own pulp mills, but the protection of our fragile environment is para-mount" (Pulp Paper Week, 1992).

In dealing with those who are informed about organochlorines, dioxins, and furans, the need for papers produced without chlorine is utmost. Those who are misinformed will cite such figures as this: 300 million tons of chlorine compounds are naturally released by seawater each year (Georgia-Pacific, 1992). But chlorine on its own is not the issue — it's the result of using it during the pulping process that is controversial.

Dioxins are 1,000 times deadlier than cyanide and thalidomide. "Dioxins do not occur naturally, nor are they intentionally manufactured by industry, except in small amounts for research purposes," U.S. Assistant Surgeon General Dr. Barry Johnson told a House subcommittee (Johnson, 1992).

Organochlorines are made up of thousands of chemicals, of which 300 have been identified, 30 fall into the most deadly category, and 700 can't be categorized. Ask the people whose wells have been contaminated.

One community has tried for two years to identify what's in their drinking water. Ground contamination surrounding a chlorine bleaching pulp mill forced these resident to drink, bathe, and wash their clothes in bottled water graciously supplied by the mill. Their own employees cannot drink water from the mill's wells (Hauserman, 1991).

This says something to us. We may be afloat with water, but don't drink it unless it comes in a bottle. The pollution is sometimes colorless, most times odorless, and all the time dangerous.

Dioxins, furans, and organochlorines are finding their way into our food chain. It doesn't matter that we are talking so many parts per million, trillion, or even quadrillion — what matters is that these chemicals are being found in dairy products, beef, pork, lamb, venison, poultry, and produce; in our water and air, and in the breast milk of nursing mothers (Schmidt, 1992). Is this the legacy we want to pass on to our children? Shouldn't they have a choice?

Chlorine-free products manufacturers are looking for partners in our industry among companies with whom we do not compete directly. We can add an environmentally sound paper to your product mix. Many of you here are part of larger organizations or operate as separate profit centers. We have products to satisfy your international and environmentally concerned customers. We believe there really is a need for chlorine-free products.

Is There a Market for Chlorine-free Products?

I receive many phone calls each day from government agencies, environmentalists, food packagers, sanitary product manufacturers, and others asking what products we make that would be suitable for their use. Each caller wants to start using chlorine-free paper in his or her operations, even if it's just for copiers. The purchasing agent for a company in San Diego, California, told me he spends $200,000 per year on copy paper and "I want to put my money where my mouth is." He thinks that many organizations want to talk about the environment but aren't willing to spend extra to make positive changes. We discussed the price differential along with limitations. He placed an order and continues to use our cut-size even with its limitations, which include high-speed copier "curl" (causes machines to jam) and brightness.

Complaints about chlorine-free paper have included poor print quality and poor performance on printing presses. Our experience has shown that chlorine-free bleached paper is equal or superior to our current competitors' bleached paper in print quality and ease of reading. A publisher of a recreational magazines who is currently using a coated No. 4 gloss sheet called us. He is concerned about the Gulf of Mexico where his photographers often work. A mutant fish called "the bearded lady," a female fish with male characteristics, has appeared in the Gulf. The breeding grasslands are being devastated by river-borne effluents. We ran a trial for him of our chlorine-free uncoated free sheet. The photos don't "pop," and some detail is lost, but the trial is a success overall. He says his company can compensate with different film to maintain the photographs' detail and high quality, and the company can still support manufacturers who offer an alternative to chlorine bleaching.

If we allow the perception to grow that our industry doesn't care about the environment, that we won't support anyone who produces chlorine-free products, and that we aren't interested in water quality or the food chain, we will be engaging needlessly in a battle we cannot win.

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Issues and Needs Affecting Paper Purchasing Decisions — An End User's View

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Time Inc. welcomes opportunities to discuss the difficult and challenging environmental issues facing the pulp and paper industries and their end users.

Time Inc. is the largest magazine publisher in the United States. In addition to our flagship, *Time*, we publish *Life, Sports Illustrated, People, Entertainment Weekly, Fortune, Money, Southern Living,* and *Sunset,* as well as several other titles. The majority of our magazines are printed on lightweight coated groundwood No. 5 paper. In 1992, we will purchase 220,000 tons of paper from domestic suppliers. In addition to lightweight coated groundwood paper, we buy small amounts of coated and uncoated free sheet. In 1992, we will purchase more than 27,000 tons of recycled paper — 12 percent of total purchases. Before 1991, we did not buy recycled paper.

Product quality is a critical aspect of our paper purchasing decisions. Our magazines' readers and advertisers demand high quality paper. This demand is a challenge for our paper suppliers, because we most often use 32-pound coated groundwood. We are forced to use lighter-weight papers because of high postal and distribution costs.

Time Inc. works closely with its paper suppliers to develop paper grades of superior quality. Our most critical quality specification is opacity. Attaining high opacity readings on a 32-pound sheet is particularly difficult. In 1990, after three years of partnership with our suppliers, we were able to reach our opacity targets and change our three largest magazines from 34-pound paper to 32-pound paper.

Other important paper characteristics are gloss, brightness, smoothness, and strength. Paper gloss and brightness enable our advertisers to showcase and differentiate their products. When a new generation of presses enters U.S. pressrooms, we will be asking lightweight paper to run through a press at speeds of over 3,000 feet per minute, or nearly 40 miles per hour. Without appropriate strength characteristics, web breaks occur and the presses shut down. Then dispatch schedules are missed, and the magazines arrive late to subscribers.

Suppliers Are Located in the United States

We buy all of our groundwood paper from mills in the United States. Generally speaking, these grades are a mix of groundwood, thermomechanical, and kraft pulps. Some of our suppliers manufacture their own kraft pulp, some of them purchase kraft from subsidiaries of their parent companies, and others purchase kraft on the open market. All recycled deinked pulp is purchased from other manufacturers.

Many factors affect our choice of paper supplier. Our mass-volume magazines must be printed on lightweight paper to minimize distribution costs;

therefore, the ability to manufacture these grades is important. Our three major weeklies are printed at eight plants throughout the United States; therefore, the geographical location of the mill is important. In addition, we spend close to $200 million per year on paper; therefore, pricing is a major issue. We favor suppliers who take innovative and creative approaches to papermaking and customer service.

These factors are important, but two other considerations are most critical in selecting a paper supplier. We insist on consistently high quality paper, and the suppliers' ability and willingness to enter into a close partnership with Time Inc. We meet formally with mill managers every two months to review adherence to quality specifications and to work on product enhancements. Informally, we talk with our suppliers daily. We believe our magazines are the best quality publications in their respective fields, and that quality must be reflected in their print and paper. We expect a great deal from our suppliers and, in return, we give them much back.

Environmental issues play an increasingly important role in our paper purchasing decisions and production methods. In 1990, Time Inc. started testing uncoated, recycled paper for use as subscriber reply cards. Today, 80 percent of our tonnage for this product is recycled. In 1990, we also started working with our suppliers on developing a recycled coated groundwood paper for use in our magazines. Following 18 months of hard work, and some resistance, the mills developed a recycled paper of equivalent quality to new paper at basis weights of 38 pounds and up. In January 1992, *Entertainment Weekly* became the first major non-environmental magazine to switch permanently to recycled stock. *Entertainment Weekly* was followed by *Parenting* in February, *Hippocrates* in March, and *Health* in April. In its November 1992 issue, *Sunset* magazine, with a circulation of 1.5 million copies, will make the switch.

In addition to the pioneering role we played on recycled paper, we have tested soybean inks, reduced our use of polybags, started a recycling program for old magazine racks, and encouraged the collection of old magazines for recycling purposes. For the last two years I have been a member of the Paper Committee of the Recycling Advisory Council. Funded by the U.S. Environmental Protection Agency (EPA), this group has performed a major public service by proposing definitions for recycled paper.

Complexities of Chlorine Bleaching

Reducing the amount of paper destined for U.S. landfills, and encouraging the use of recycled products is a relatively straightforward issue compared to the complexities surrounding the issue of chlorine bleaching. Many diverse opinions exist on this issue.

Many would argue that the paper industry has already spent over $1 billion to reduce dioxin and adsorbable organic halogens (AOX) levels and have done so dramatically, primarily through high levels of chlorine dioxide substitution for chlorine and through the use of oxygen delignification. On the other hand, some groups believe that only a complete switch to totally chlorine-free (TCF) paper can bring mill effluent dioxins down to acceptable levels.

These are complex issues. Are there right and wrong answers? We may never know. Some of the latest studies are chilling and raise some serious issues, but what is a feasible answer? Is ozone bleaching a solution? What levels of dioxin and AOX pose a threat? Until these questions can be answered with reasonable certainty, it seems foolish for paper and pulp mills to spend billions of dollars chasing the last chlorine molecule. Do we know what the potential dangers are of ozone bleaching? Is sulfite pulping more of an environmental concern than chlorine bleaching? Is the use of TCF paper in conflict with the use of recycled paper? These are not easy questions to answer, but, answers need to be found so that all sectors of the industry and its end users can make rational decisions.

Conclusion

Time Inc. wants to be a leader in environmental issues. Afterall, we are the ones who named the Earth Planet of the Year in 1988, instead of designating a Man of the Year. We have been a pioneer in the development and use of recycled coated paper. One day, after scientists have reached a consensus, society may determine that billions should be spent on new bleaching methodologies. The paper industry's research and development capability needs to expand so that if this day comes, industry will be ready to respond. This transition will take time, however, and the quality concerns noted earlier cannot be ignored. Before the paper industry is forced to spend this money, we had best make sure that it is indeed the prudent course to take. None of us can afford to make the wrong choice.

Apple Computer's Project Jordache — The Switch to Kraft Packaging

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Late in 1990, several Apple groups involved in the specification and use of paper products formed an environmental task force. The task force's goal was to examine the company's practices to determine whether they could improve Apple's environmental performance relative to paper products. Members of the task force represented a wide range of company functions, including

- **Creative Services** — responsible for Apple's visual image, its creation and the technical specifications necessary to maintain the Apple look;
- **Instructional Products** — responsible for user manuals;
- **Packaging Engineering** — responsible for the specification and testing of protective packaging materials;
- **Worldwide Supply Base Management** — responsible for managing and qualifying our vendor base;
- **Worldwide Product Marketing** — responsible for ensuring customer-driven solutions; and
- **Environmental Health and Safety** — responsible for providing technical environmental assistance.

The task force identified protective packaging as an area in which environmental improvements visible to the customer could be made. Project Jordache — Apple's code name for its packaging redesign project — was born.

Product Objectives

The project had several objectives. First, the task force wanted to revitalize Apple's product packaging to show design improvements and innovation. Second, it wanted to use environmentally preferable materials. Finally, the task force strove to reduce packaging material and production costs. These objectives were to be met with Apple's existing standards for packaging strength and product protection. A communications plan, materials investigation, sourcing investigation, printing and shipping tests, and a return-on-investment model were developed to define the project parameters.

The communications plan outlined what Apple hoped to communicate to customers through the new design. The design was to reinforce Apple's reputation for innovation and change. It was to be a bold and confident design. It had also to respond to a changing market and to changes in Apple's distribution strategies.

When Apple first introduced its "white box" packaging and computers, sales were largely confined to exclusive Apple dealers who used trained staff and product demonstrations as key in-store features. As computers proliferated in the marketplace, however, many consumers became more savvy and more price-conscious. They no longer needed retail consultations, and they demanded lower prices. In response to this trend, Apple has moved to new distribution channels, such as computer superstores and consumer goods retailers. These channels demand a box design with high shelf impact that can also be a stand-alone display item.

The materials investigation team researched ways to improve environmental sensitivity in packaging. The bleached white outer liner of Apple's boxes, the hallmark of Apple's "white look," was targeted for change. A wholesale changeover from the white look to kraft was considered, as were alternative whites, such as 100 percent postconsumer office paper. Postconsumer recycled content was established as a target for all liner options.

To achieve the environmental advantages offered by kraft liners without losing Apple's "white" identity entirely, the materials investigation also suggested using white ink on the kraft liner.

The sourcing investigation turned up few liner options. The alternative whites were not available on a worldwide basis. (Apple's procurement strategy is to use materials local to our manufacturing sites whenever possible. In addition, the materials must be available to our original equipment manufacturers around the world.) Nonchlorine bleached white liner was not investigated in any detail; even in initial discussion the kraft option was highly rated with both the environmental and bold design change objectives.

The sourcing investigation also revealed that kraft liner was widely available, in most cases from existing suppliers. The kraft color, however, varied from region to region. European kraft was a chocolate brown; Asian kraft was almost yellow. The white ink was also widely available, though the print quality varied from supplier to supplier.

The printing and shipping tests were designed to test the performance of the identified material options under realistic use conditions. No. 1 white ink, black ink, and colors were printed on a variety of kraft liners by different suppliers. Test boxes were packed with products and shipped using normal Apple shipping channels to determine the impact of shipping on the materials' visual appeal. These tests revealed some important factors for application later in the design process. The white inks could be printed successfully on kraft, and had a tremendous visual impact; however, their print quality was inconsistent. Some samples were blotchy, and some printers had difficulty running the ink.

The shipping test also demonstrated a striking difference in visual quality between original Apple white boxes and the test kraft boxes when the end user received them. Apple knew that the white boxes created problems for some resellers because they were dirty and scuffed after shipping. Apple distribution centers routinely rejected dirty boxes and replaced them with Apple boxes that had been sent separately. This practice created a fair amount of waste, both environmentally and economically. The kraft boxes, though equally scuffed and dirty from shipment, did not appear to be so badly damaged. The task force estimated that a switch to kraft boxes could result in a 40 percent reduction in box rejects.

The return-on-investment model was the initial cost investigation. It estimated the capital required to make a complete design change, and compared those costs to projected savings based on the materials and sourcing investigations and the printing and shipping tests. The total project costs were estimated to be $400,000, and the projected savings, based on a kraft liner, totaled more than $3 million for the first 18 months of implementation. These savings derived largely from a materials cost reduction of approximately 50 percent.

Product Design

Based on these encouraging results, Apple proceeded with the box design. The artists were given free rein to develop a new look for Apple. They were told only that the design would be produced on kraft boxes, that the boxes should be limited to two colors, and that Apple was interested in exploring white ink. The designers produced a wide variety of designs, the most promising of which were printed on test boxes for consumer research and presentation to Apple senior management.

Apple conducted consumer research in the United States, Germany, France, and Japan to determine whether the box design would positively or negatively affect consumers' intent to purchase an Apple product, and whether the brown box communicated that the product was technologically advanced. The research indicated that consumers' intent to purchase was somewhat negatively affected by the brown boxes, until they were informed that it had environmental benefits. At that point, they changed their opinion and were either neutral between the boxes, or favored the brown boxes.

Research also indicated that all box colors (white and the three shades of kraft) were equally effective at communicating the message of a technologically advanced product in the United States, while in Europe and Asia, the white and medium brown boxes were somewhat more effective at conveying this message than the dark brown and yellow-brown boxes.

The task force also surveyed the manufacturing sites that would be responsible for localizing the box design, procuring materials, and managing the original equipment manufacturers. They emphasized the need for generic product images with few

words to simplify localization, the need for local materials and supplier availability, and a concern regarding labels unrelated to the new design.

With this research completed, the task force presented the project to Apple senior management for approval to go ahead with the new boxes for the fall 1991 product introductions. The project was approved, and the task force proceeded to implementation.

Implementation

The implementation phase included identifying and qualifying actual suppliers, and identifying a product cost outlay model to determine which Apple products were close enough to obsolescence to forego redesigning their boxes. Then we had to create the final design (and artwork for other products), identify production constraints among our direct suppliers and our original equipment manufacturers, confirm the environmental benefits of the design change, and decide on the educational and promotional plan for the new box. These phases were prerelease absolutes; in addition, Apple needed to update the print/packaging supplier qualification documents and the Apple Print Production Standards binder to reflect the new design.

Although most of our existing suppliers could supply kraft boxes, it was necessary to identify and qualify additional suppliers to ensure materials availability, cost, and quality. At the same time, we examined the availability of postconsumer content at these suppliers to meet our increased recycled content objective.

The product cost outlay model showed that for each of approximately 150 products on the market, the changeover to a new box would cost approximately $1,700. The ongoing cost savings attributed to the new design was about 50 cents per box. Therefore, Apple would need to purchase at least 3,400 boxes of any particular product for the design change to "pay back" for that product. The new design was not implemented for products that were either so close to obsolesence or sold in such small quantities that they would not "pay back."

The final box design and artwork reflect a black design, with a heavy dot photograph of the enclosed product. The product identifier (for example, "Macintosh IIsi") was designed in white, though the option remained to print it in black, or to print some in black and some in white. The design required no color separation, so only one film was prepared for each product. In the final stages of implementation, the decision was made to print our major product lines with the white identifier, while others were printed in black. This decision meant cost savings, and allowed Apple to control the quality of the white ink suppliers very strictly.

Inconsistencies among suppliers of the white ink printing remained the key production constraint. The white ink suffered from contamination problems at some printers, thus darkening the final printed boxes, while other printers had trouble running the viscous ink in their machines. Rather than attempt to address these issues at all printers, we decided to focus on using white ink for our major product boxes, while allowing the original equipment manufacturers' product boxes to be printed using black ink only. This decision reduced both the cost and the time associated with implementing the change at our original producers, though the visual impact of the all-black boxes is somewhat less than the black-and-white combination.

A critical component of the implementation phase was to determine, for our particular supply base, whether the switch to kraft boxes would actually result in environmental benefits. We contracted with Scientific Certification Systems, Inc., (SCS) of Oakland, California, to assist us with this determination and to provide a third-party analysis. SCS compared the environmental effects of three corrugated box liners: bleached (white) liner, with all virgin materials; unbleached (brown) liner with all virgin materials; and unbleached (brown) liner with high recycled fiber content.

They surveyed seven linerboard mills, five in the United States and two in Scandinavia, in order to establish environmental performance in the areas of resource use, emissions, energy use, and toxic and hazardous waste use and release. The data were collected from the suppliers themselves without the benefit of an audit. However, the data derive in large part from legal requirements such as permit monitoring and community-right-to-know submissions. Their validity rests on the force of these legal requirements.

The mills surveyed represented current and prospective suppliers to Apple operations. The survey conclusions showed that converting Apple corrugated cardboard packaging from bleached virgin to unbleached virgin will result in the release of fewer toxins — organochlorine compounds, such as dioxin, furans, and chloroform — into the environment. Converting from bleached to unbleached virgin pulp will also reduce the energy required to produce Apple packaging for similarly designed and operated mills. It may also reduce the amount of water pollutants.

It was more difficult to generalize conclusions regarding the incorporation of high recycled fiber

content, though the one mill surveyed that manufactured only 100 percent postconsumer unbleached liner was clearly the superior environmental performer.

The final implementation step was to decide on a consumer education plan. Our research had shown that customers preferred the brown box when they were informed of its environmental benefits, but that those benefits were not apparent without information. Therefore, we developed and inserted into each package a small flier that explains the box's environmental benefits. The flier is now being replaced with a permanent, shorter message on the outside of the box.

Conclusion

The Jordache Project continues to meet as the Apple Print and Packaging Environmental Task Force, which is chartered to effect the continuous improvement of Apple's print and packaging materials. The task force has established specifications for recycled content in corrugated boxes, analyzed several alternative protective packaging materials and systems, and ensured that Apple's packaging suppliers do not use heavy metals in their packaging materials. Future focus areas include paper in our user manuals and a continuing reduction in the volume of packaging present overall with Apple's products.

Panel 2:
Technical Perspectives—Specifications

Question and Answer Session

■ **Richard Phillips,** *International Paper:* Question for Mr. Beaton. I wonder if in the process of extolling the virtues of your chlorine-free paper, you tell your customers that you discharge 3 times the amount of BOD, 5 times the amount of SO_2, and 20 times the amount of color than another well-known mill in the state of New York? And do you tell your customers that your paper contains measurable levels of chlorinated furans?

■ **Archie Beaton,** *Lyon Falls Pulp and Paper:* Those are technical things that I am not prepared to discuss. I'm a marketing person, not a technician.

■ **Richard Phillips:** You must know whether you tell your customers those things. You told us what you tell your customers.

■ **Archie Beaton:** I don't think that we got definitely into that. I tell our customers that they have an opportunity to buy something that we can provide. There are customers who are looking for chlorine-free products. We produce a chlorine-free product that meets their needs. That's all.

■ **Richard Phillips:** So you tell them a very small fraction of the whole environmental story.

■ **Archie Beaton:** As I think many of us do.

■ **Barry Patrie,** *Stone and Webster Environmental Services:* Mr. Sproull, in your use of the terminology for chlorine-free papers, are the products that you sell chlorine element-free or totally chlorine-free? What is the definition of chlorine free in your products? In 100 percent of them?

■ **Howard Sproull,** *ECO Paper Source:* Thank you. That is a good question. I meant to clarify that before I started, because it is a nomenclature problem. The possibilities are elemental chlorine-free, molecular chlorine-free, totally chlorine-free, chlorine-free, and chlorine dioxide-free. The only term that is not confusing is totally chlorine-free and the products that I deal with are all totally chlorine-free.

■ **Archie Beaton:** From the Lyons Falls standpoint, we do not produce every product that we make 100 percent chlorine-free. All the pulps that we produce are chlorine-free. We produce about 70 percent of our own pulp. We need to purchase 30 percent of that pulp on the open market. That 30 percent pulp is not chlorine-free. So when we are producing a chlorine-free product for the customer, we will purchase the softwood chlorine-free pulp to produce the 100 percent chlorine-free product.

■ **Barry Patrie:** Is that totally chlorine-free?

■ **Archie Beaton:** That is totally chlorine-free.

■ **Barry Patrie:** Even the ones you produce yourself?

■ **Archie Beaton:** All the pulp that we produce ourselves. No chlorine dioxide used at all.

■ **Jens Folke,** *Environmental Research Group, Denmark:* Some of these issues, totally chlorine-free papers and papers containing recycled fibers, originated in Europe. To give you a perspective of why this is so, I'll use two minutes, if I may. As we said yesterday, the Germans have the largest pulp and paper market in Europe. They have about 13 mills that are all sulfite mills. The only competitive edge for a sulfite mill is that it's an easier pulp to bleach. Thus, the Germans were interested in getting the AOX level down to zero because that would increase their competitive edge.

Now, they have a similar interest in recycling because every piece of paper that is sold on the German market contains a certain amount of secondary fibers. And why is that? Because all the virgin fibers are supplied from Norway, Sweden and Finland. If you persuade the consumer to buy paper with secondary fibers only, the result will be that rather than expanding a mill in Norway you will expand a mill in Germany. The consequences, just to take the recycled fiber, is that in Scandinavia and northern Germany you have an excess of about 5 million cubic meters of wood that is very well suited for pulp.

The way we grow the forests may be slightly different because it's a sort of plantation. We plant the trees and they grow for approximately 70 to 150 years. We harvest it twice during that period, and thin it. These thinnings are utterly important for the whole economy of the forest because if we don't thin them, then the wood at the end will be of poorer quality and the whole economy of the forest would decline including the replantation projects.

So. This recycling would put all the Swedish paper machines idle and give the capacity to Germany instead. Sweden, Finland, and Norway would become merely a pulp supplier to the central European market. I think it's important to understand the market forces behind pollution control and these remedial issues. I'm not going to discuss whether recycled fiber makes good or bad paper but the most important thing is to control the waste. It's the waste you want to eliminate from your cities and dumps, and if you do, you'll be okay. Collect all the waste paper. But remember there's another use for waste paper, namely energy, the substitute for fossil fuels. If you take all the waste paper in Munich and ship it back to Sweden, I suggest you install a steam engine in your ship and feed it with all the paper. See how much is left when you get back to Sweden.

■ **Mark Floegel,** *Greenpeace:* I have a question for David Refkin. I was interested in your presentation and your partnership with mills to get from 34 lb down to 32 lb papers and the 18 months it took to get to recycled content. I have also had conversations with folks at *Time* and as a result *Time* published an announcement in January regarding chlorine-free paper, saying that *Time* is interested in chlorine-free paper and intends to switch to chlorine-free paper when it becomes practical to do so, in terms of quality and cost. I am surprised you didn't address that in you remarks today. Since that time I have heard talk from within the industry and from various government regulators, that *Time* is backing away from that statement. So I've got a printed statement on the one hand and a lot of backscatter on the other. Is *Time* backing away from its statement? I was wondering if you could clear the record for us today.

■ **David Refkin,** *The Time Inc. Magazine Company:* What I tried to do in my speech was outline the publishing side of our position on this topic. Since 1923, I think, *Time* has had a reputation within the publishing industry of having a separation of church and state; that is, our editorial side operates independently of our publishing side and vice versa. What was printed in *Time* magazine in January was the viewpoint of the editorial side of our business, not necessarily the viewpoint of the publishers.

What I tried to outline today was the fact that we are an environmental company; we've done a lot of things in that direction. However, before we jump in one direction or another with regard to the issue of chlorine-free pulp, we still have many questions that need to be answered. I don't think there's been a consensus reached on the evidence yet. When and if a consensus is reached that the industry needs to change, then *Time* will support that change. But I don't think we've reached that position yet.

■ **Mark Floegel:** For clarity, on two points — one on mine and one on yours. I didn't speak to anyone on the editorial side. I spoke to your boss and your boss's boss on the publishing side. What you're saying is that you are not working in partnership with your suppliers to develop a chlorine-free paper like you worked in partnership to develop the recycled paper and like you worked in partnership to develop the lighter weight.

■ **David Refkin:** At this point in time, the answer is that we are not.

■ **Steve Levitas,** *Environmental Defense Fund:* My question is for Mr. Sproull. I'm curious to know to what extent your company is involved in marketing reduced brightness papers if high brightness is not essential to functionality? I'd like to know if you are doing that, what your experiences have been in overcoming the education and perception obstacles that you identify?

■ **Howard Sproull:** Brightness levels come into a performance category and really depend on what a particular end use might be. Quite frankly, I very seldom hear any objections to brightness. So in that respect, it's not so much a part of the education process.

■ **Steve Levitas:** Are you marketing any products, whether file folders, legal pads, or copying paper, that have reduced brightness? If so, are you finding consumer acceptance?

■ **Howard Sproull:** Basically, I'm involved with printing papers, not so much with converted products like folders and so forth. The lower brightness is only relevant to one area of the paper that I sell. In that respect, the people buying that product have no objection to it. There are obviously people that I've talked to that do have an objection to lower brightness and don't buy the product, but reduced brightness may not be the only reason.

■ **David Assmann,** *Conservatree:* I have two questions for Virgil. First, the chart you showed at the beginning of your presentation with recycling at the top and resource reduction at the bottom, turns the traditional reduce, reuse, recycle notion upside down, but my question is the second item you have on that list, namely, waste-to-energy. I have a copy of a chart that API put out that lists the sources of dioxins in the atmosphere, and at the top of the list is municipal waste incineration. How do you make that consistent with having waste-to-energy as the second item on your list in terms of pollution prevention?

My second question concerns the chart that shows a graph of wastepaper use rates that starts at 24 and goes to 30. Of course, it looks impressive when you take only a small part of the scale, but how can we say that it is adequate when it's well below the global average? Slovenia, for example, has a 72 percent wastepaper use rate. Venezuela's rate is 60 percent. We're running way behind a lot of other countries. Those are my questions.

■ **Virgil Horton,** *American Paper Institute:* Let me answer your first question very straightforwardly. I think I mentioned that those items on the chart were not necessarily in the hierarchical order that we are accustomed to. It was not meant to show any rank order. It was a matter of when I wrote the items down to prepare a slide — that's the way they came out, and that's the way I used them. I had no intention of changing the hierarchy. There was no ranking order, but the slide looked better.

With reference to our collection rate, I think if we are objective about it, we must look at countries like Germany and Japan where the recovery or collection rate of wastepaper is somewhere between 48 and 50 percent on a national average. Japan has been at this for well over 30 years. It took them some time to obtain the 50 percent rate, and they have difficulty maintaining it. They keep dropping to 47 and a fraction, or what have you. The same thing is true in Germany. I believe what my slide showed was a very significant increase. Whether you put it on a large or small scale, going from where we were to where we are in a matter of three years is a rather dramatic increase.

This increase is like saying that President Bush started at a 37 percent favorable rating in the polls and suddenly hit 52 percent. Gee, he started at a 37 percent base. Still, I think he'd be happy to have a 52 percent rating right now. That's the image I would apply to our collection rate, David, though you and I may politely disagree. I think we have something we can truly hang our hat on, and I do not feel that we are so woefully slow. If anything, I think we are showing a tremendous commitment. The other thing I wanted to point out that was not mentioned in your question is that this improvement has occurred during an extended recessionary time.

■ **David Assmann:** Just one final thing on that. Our wastepaper use rate in 1951 was 32 percent.

■ **Judy Usherson,** *Center for Earth Resource Management Applications, Recycle Paper News:* I have a comment for Mr. Sproull, who seems to be pitting chlorine-free paper against recycled paper as a marketing strategy. I think that's unfortunate. I believe recycled papers are making a significant contribution to several sets of environmental problems. We work very closely with major high-volume printers and others interested in the subject of recycled paper, and the performance deficiencies that Mr. Sproull cited do not seem to pan out when we talk to these people. The Center for Earth Resource Management would be very pleased to put you in touch with printers and users who are very, very happy with the high quality of the recycled papers they are using. I would also like to comment that importing totally-chlorine free papers from other countries is not doing anything to encourage the paper industry in North America.

■ **Richard Valley,** *Michigan Pulp and Paper Corporation:* I have a question for the panel generally. We've been talking about brightness loss when we get away from chlorine bleaching. We've been talking about some vague level of brightness. Now historically, if we wish to go back 10, 15, 20 years, when we talked about a white paper then, we were talking 90 brightness, 90 ISO brightness. We talked about semibleached papers below 80. Semibleached implies that they were not fully bleached; they were not white. They were something less than white, creamy, if you wish, or slightly yellowish. Would the panel care to comment on what their customers perceive as "an acceptable white paper" today in terms of ISO brightness? Above 80, above 82, above 85? I'm just curious because we talk so vaguely about brightness, and I think it's a very important property of paper, particularly of pretty paper.

■ **Virgil Horton:** I'd like to comment on that based on my 27 years experience in the industry of selling and marketing. One of these days I'm going to become a consultant to the paper industry like some of the younger people. They're learning faster than I am. When I talk brightness and whiteness, they are not the same. I think it is very important to know what the printed piece is going to be. And, obviously, there's a difference between coated and uncoated.

Now when you look at API statistics, we break the brightness range into 1's and 2's, and our premium brightness papers are 1's. The industry of designers, publishers, and printers accept one range; others may accept something else. There is also a publication called the competitive grade finder. So the "brightness level" becomes a discussion about a number 1 sheet, a number 2 sheet, and a number 3 sheet. If someone were to put number 1 or 2 uncoated bond through a copy machine for everyday office copies, that's really not needed. Instead of buying a number 1 or 2 uncoated sheet they could buy a 3 or 4; and whether it was totally chlorine-free, virgin or recycled, would also make no difference — as long as it performs for the end use. That's my rule of thumb for all my years of experience. That's really where it's at in terms of brightness. Now, let's go to whiteness. Whiteness is a color.

■ **Richard Valley:** That's not the question I'm asking. I agree, that there are number 1 and number 2 sheets. But what, for instance, is the minimum ISO brightness for a number 2 sheet? Just so we're all more or less on the same level.

■ **Virgil Horton:** I don't have the numbers in front of me. But there is an accepted brightness level that says this sheet is a number 1 as viewed within a brightness total.

■ **Richard Valley:** There are ranges, agreed. But what does it mean when someone says, "Yes, I can substitute a number 3 sheet"? I'm also a great believer that we spend an awful lot of money making white paper we don't need and ignoring the environment. We buy an awful lot of extremely white paper that glares at you when you read it. But that's beside the point. The question again comes down to this simple statement: We don't need all this brightness. What brightness do we need?

■ **Virgil Horton:** It depends on the end product.

■ **Richard Valley:** That's extremely important to keep in mind in our overall discussion.

■ **Archie Beaton:** Let me comment on that. One thing that I've noticed is that our papers have only a 77-78 brightness level that doesn't fit every application, which is what Virgil was talking about. However, I've got printed samples here, and the way I address the issue is by asking the customer, "Are you printing something that's going to have full coverage? Is the reverse white out that's in this paper going to make a difference in the quality of the print job? No. Are there cost savings? Yes. When you're printing something that will fill the page, it doesn't really matter if it's an 80 brightness or an 86 brightness. Whiter than white is an old advertising maxim, an old chestnut that conjures up images of something pristine and crisp and clean. It was all brought on by advertising agencies. I think really that the cry I'm hearing among some of our customers is that beige is better.

■ **Ann Hillyer,** *West Coast Environmental Law Association:* Some work is beginning to be done in British Columbia on an industrywide basis looking at or trying to look at the emerging market for totally chlorine-free products in respect to customers of the pulp companies in British Columbia. My question is for Mr. Horton or anyone else on the panel who can answer it. Is there industrywide work going on in the United States to get a handle on what that emerging market is? I've heard a lot of discussion about individual companies and individual customers, but I'm wondering if, on a broader basis, there's any effort to analyze the projected buying patterns of companies in the United States. Will there be a market for totally chlorine-free products or some of the other categories that we have talked about? And second, has any analysis been done on the number of mills that are anticipating bringing some of these products on line and their actual time frames for that?

■ **Virgil Horton:** Is API doing anything nationwide was your first question. From API's perspective, market analysis is something that belongs to the individual companies because, obviously, our member companies have the right, the opportunity, and the wherewithal to choose their bleaching systems. API does not, as an association, promote chlorine bleaching or totally chlorine-free bleaching. We have membership on both sides of the issue. What we do want to protect are their individual rights. From an industry perspective, and contrary to what Archie may have said a little earlier, it is our feeling that not too much has yet been proven. There is some junk science out there. We need better science to determine what really is the case when it comes to chlorine bleaching or totally chlorine-free bleaching. The question comes down to — and Mary I'm sorry I gotta say this — "Where's the beef?" Is it really necessary, for whatever reason, to

embrace totally chlorine-free bleaching? That's up to the individual companies to determine. It's up to them to determine which market niche they, in fact, want to fulfill. It's part of their marketing.

■ **Ann Hillyer:** My question wasn't whether or not you agree with the market trend. It was whether or not the industry here is trying to anticipate the market trend. Just like people who manufacture cars want to know whether in five years people will want small or big cars. Is there any comprehensive work being done to analyze the trends?

■ **Virgil Horton:** It's still a marketing question for individual companies and not in the purview of our association.

■ **Med Byrd,** *North Carolina State University:* I'd just like to make a comment. I think we can see, even in these brief discussions, the volatility and complexity of the issue surrounding environmentally compatible processes and paper products, but I think that it's really important. Dr. Phillips commented on an important aspect of it, namely, that we, as an industry, must maintain a reasonable, rational, research-based and systems view of the ultimate solution: the production of good quality products with good environmental performance.

If we only meet short-term consumer demands, public demands, whether rational or not, will escalate. If we all rush lemminglike to the next bleaching or pulping process that shows promise without maintaining an overall systems analysis of what we're really doing, we could end up with inferior quality products. We could end up harming the environment by simply trading water pollution for air pollution, toxins in one place for toxins in another place. It's important that we maintain our grounding in good science and examine systematically what the final solution needs to be. If we do that, we're going to come out okay.

■ **Bruce Fleming,** *Boise Cascade:* I have a comment and a question for Mr. Sproull. I was very disappointed to hear you come out so strongly against recycling because my company is moving very quickly in that direction — and this is true for the industry as a whole in the United States, as we heard Mr. Horton say. So I wasn't pleased to hear you so down on recycling. My question concerns the nature of the chemical pulp that goes into your chlorine-free paper. I'm trying to figure out what it must be. Is it sulfite pulp that you put in the chlorine-free paper?

■ **Howard Sproull:** The suppliers that I work with manufacture totally chlorine-free paper. A number of them are from Germany, and one is from Holland. The pulp sources that they use are various. Two of the mills are fully integrated; another is sourcing pulp on the open market that's chlorine-free. The integrated facilities use the sulfite-based process, but I'm not certain of the fiber supply in the nonintegrated facilities.

To answer your comment about my being down on recycled papers. I did not want to leave that impression. What I really meant to do, basically, was to show the perceptual barrier to other alternatives that people wrap themselves up in by saying that they use recycled paper. What I tried to do is open us up a little, to help us realize that recycling is not the only answer. In the process, I do question these people about the "recycled" paper they're using.

I can give you a case in point without mentioning any names. A year and a half ago, I was talking to a designer about using chlorine-free paper as an alternate in a high-end, highly visible publication for a health care organization. And they basically did nothing with it. When I called them back, about a year later, they said "Oh, we're using recycled paper." And I said "What is the grade and the name of the paper that you're using?" They told me, and I said, "Well, does that have any postconsumer content?" But they didn't know. So I said, "Isn't that why you're using recycled paper to demonstrate some meaningful impact on landfill, and isn't postconsumer content the only true measure of the recycled paper's impact on landfill?" "Well yes," they said, "but we don't know." Of course I already knew that it had no postconsumer content. So what I say is, I'm not down on recycled paper. I'm sorry again, if I left that impression; I'm absolutely not. What I'm exposing is the fact that people want to do something for the environment but tend to cloister themselves within a choice once they've made it. That's really the point I was trying to make.

■ **Bruce Fleming:** One final comment. You said that printers love the chlorine-free paper that you're supplying. I think that part of your talk would have been more impressive had you given us data to support that statement, perhaps showing what type of press they were using, and its running speed and so forth.

■ **Howard Sproull:** I can comment very briefly on that. Basically, the product is a sheet-fed coated paper, a number 1 quality, that prints on sheet-fed, five-unit or more, 40-inch presses, running anywhere from 8,500 to 12,000 impressions per hour. Its performance characteristics include a minimal amount of make-ready time, and printers also report that a minimal amount of wash-up is required. Again, I'm not down on recycled paper. But

when pressmen run recycled paper, they tell me they're pulling their hair out, fighting the stuff. I'm exaggerating perhaps but also reflecting their comments. What they usually mean is that they're chasing hickeys through it. They've got to stop and wash the blankets every 3,000 to 4,000 impressions and that does not happen with chlorine-free paper. In fact, in one particular case, the printer mentioned that he'd run 8,000 impressions without stopping to wash the blanket and when he looked at it, indeed, there was no need to do so.

■ **Virgil Horton:** Obviously, I represent recycled mills and virgin mills, so when a statement like this is made I have to say something, in all fairness, to protect my recycling mills. I think it's a known fact in the printing industry that the longest-held view prevails. Sometimes if you just let a pressman know he's dealing with recycled paper, it won't work. When I was in sales, if we went into pressrooms where the front office wanted to buy a paper and the pressman absolutely knew it wouldn't run, if we did little things like change the wrappers on it, it was amazing how well it ran on the third shift. So while there are some problems with recycled paper in terms of print quality, there's also some problems with virgin sheets. We do have excellent recycled sheets that will perform well for their intended use.

■ **Susan Cohen,** *Environmental Defense Fund:* May I suggest a number on the brightness issue? Random House uses a free sheet in its trade hardback books that is about a 77 brightness.

The Right Balance — Environmental Responsibility and the Competitive Edge

Clifford T. Howlett, Jr.
Vice President, Government Affairs
Georgia-Pacific Corporation
Atlanta, Georgia

The pulp and paper industry in the United States has invested billions of dollars over the last 20 years to meet standards set by the Clean Air and Clean Water acts as well as hazardous waste laws. Our air, water, and land are cleaner now as a result. But groups outside the industry are pushing us to implement ever more drastic environmental actions that provide little or no benefit to human health or the environment beyond the significant benefits we have already achieved. Nevertheless, these ideas have the capacity to fundamentally affect the competitive structure of the industry worldwide. Three key issues dominate: first, what do we mean by chlorine-free? Second, what is the industry being asked to reduce, and what benefits will be gained? Third, and finally, what are the economic impacts of these changes?

Pollution Prevention Progress

Let's consider the progress this industry has made in pollution prevention. Today, U.S. mills are already meeting effluent pollutant discharge levels that are targeted for 1995 by other paper-producing nations. Our industry uses 60 percent less water per ton of product than it did just over two decades ago. Since the Clean Water Act's implementation, the total biological oxygen demand (BOD) of industry wastewater has been reduced by 70 percent, while paper production has increased by 50 percent. The pulp and paper industry is among the world's most efficient users of fuel. Through use of waste by-products, our industry produces more than 56 percent of its own energy needs. Over the last two decades, oil consumption has been reduced by more than 60 percent, and fossil fuel and energy consumption per ton of paper have been reduced by almost 50 percent. To put that in perspective, because our industry cogenerates more than 50 percent of its electricity needs, we save 24 million barrels of oil annually. Industry air pollution control technologies now remove more than 97 percent of the particles generated in the pulp and papermaking process. Virtually every new solid fuel boiler and piece of process equipment achieve a particle removal rate of almost 100 percent.

The U.S. pulp and paper industry is the world's largest paper recycler, recovering almost 31 million tons of paper for reuse last year. We have set a goal of 40 percent recovery by 1995.

On the resource side, last year the U.S. forest products industry planted nearly 1.7 billion seedlings. Twenty percent more forested timberland exists today than 20 years ago. Georgia-Pacific and other U.S. pulp and paper manufacturers are also participating in U.S. Environmental Protection Agency's voluntary 33/50 pollution prevention program. In fact, the industry has already realized EPA's goal for lowering dioxin discharges, reducing them by 80 percent. Georgia-Pacific's efforts here have resulted in nonmeasurable levels of dioxin in 9 of our 10 bleached mill effluents. We have committed the capital to achieve this nonmeasurable result at the remaining mill, which even now meets its state's dioxin water quality standard. We are well on the way to meeting the other pollution reduction goals for the 33/50 program (see Fig. 1).

The U.S. industry recently adopted its own set of environmental, health and safety, and forestry principles that formalize our commitment to a

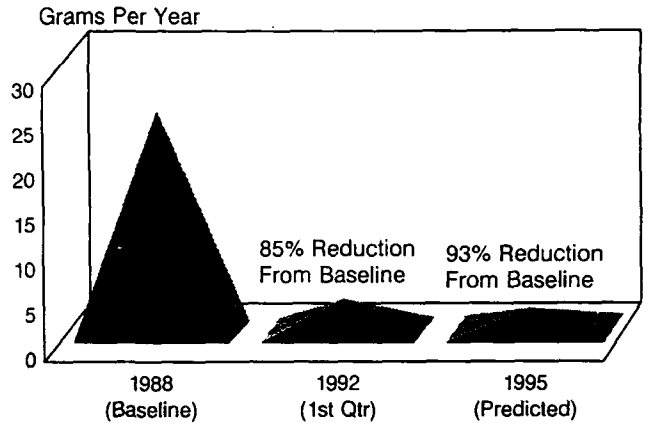

Figure 1.—Georgia-Pacific Corporation EPA 33/50 plan summary: dioxin effluent reductions. Dioxin expressed as 2,3,7,8-TCDD and 1/2 of detection limit concentration used for nondetect values. Annual nominalized effluent values and single quarter effluent analysis used in calculating mass values. Facilities having nondetect in baseline, and all other samples, are excluded.

healthy environment. With these accomplishments and ongoing initiatives, I believe the U.S. pulp and paper industry is meeting the pollution prevention challenge.

Let's put these efforts into perspective. As Figure 2 illustrates, the industry contributes about .25 percent to this country's Gross National Product, and yet, we account for nearly 2.5 percent of total U.S. industry expenditures on pollution control. Certain environmental factions, however, do not believe that this is enough. They believe that whatever industry does, it will never be enough to safeguard public health and the environment. That attitude has led us to a critical juncture in the history of the pulp and paper industry — specifically the heated debate about the use of chlorine compounds to bleach pulp and paper products.

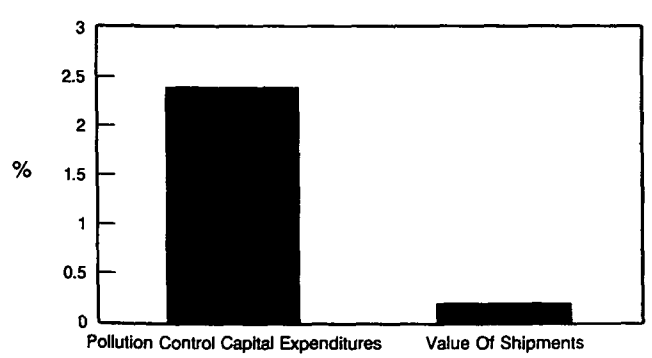

Figure 2.—1986 to 1990 pulp mills share of U.S. industry pollution control capital expenditures is five times their share of value of shipments.

Defining Chlorine-free

Does chlorine-free mean reducing or eliminating the use of chlorine gas with chlorine dioxide substitution? Do we measure success in the reduction of chlorinated organics of concern? Or do we mean the use of no molecular or elemental chlorine anywhere in the manufacturing process? The answer is that trying to make the world chlorine-free, as some organizations would like, is impossible because nature is replete with chlorinated organics. As reported by the Swedish Environmental Protection Agency, more than 220 million tons of chlorinated organic compounds — nearly 3,000 times the amount discharged by the U.S. paper industry — are produced naturally by marine organisms in the Atlantic Ocean each year.

The next question we must answer is, "What is the industry being asked to reduce, and what benefits will be gained?" Most environmental groups are stressing the elimination of bioaccumulative chlorinated organics. Are they talking about dichlorodiphenyltrichloroethane (DDT)? It's not produced by the pulp and paper industry. Polychlorinated biphenyls (PCBS)? Not us, either. Dioxin? The U.S. pulp and paper industry has virtually eliminated the problem. In fact, pollution control measures in the United States have already led to substantial reductions in all chlorinated organics. All chlorinated organics are not created equal. Most are benign, although a few may be toxic, including some of those produced naturally. Only a tiny fraction of all chlorinated organics are generated by human activity. At a typical pulp mill, 90 percent of the chlorine used in the bleaching process ends up as common salt, while the remaining 10 percent combines with the various constituents to form chlorinated organics — 99.96 percent of which are benign.

To put exposure levels into some perspective: based on current available scientific information used to determine the "no observable adverse effect level" (NOAEL), the concentrations of each chlorinated organic, when present in mill effluent, are below the NOAEL for these compounds.

The EPA effluent guideline program focuses on 28 chlorinated organics that it considers of concern. Only 10 of the 28 are found in bleached pulp mill effluent, and those only occasionally. So using the level of adsorbable organic halogens (AOX) in the effluent as an environmental measure requires caution. AOX is not a reliable indicator of environmental effects because it doesn't pinpoint the organics of interest. It is a relatively inexpensive analytic chemistry indicator of the presence of all chlorinated organics in the waste stream. AOX also fails to consider issues of equal importance to the

environment, such as what environmental benefits will be gained? All indicators today say that the environmental benefits to be gained from eliminating the use of chlorine compounds in the pulp bleaching process are insignificant.

Advanced methods in aquatic biology and chemical analysis are being used to examine the potential environmental impacts of current and new technologies. To date, there are no indications that totally chlorine-free (TCF) technology is environmentally safer than chlorine-based processes. Bleaching per se may not be the relevant issue. In fact, at a 1989 Technical Association of the Pulp and Paper Industry conference, an international panel of scientists concluded that no marked difference exists in toxicity between properly treated chlorine-bleached and nonchlorine-bleached effluents. In addition, effluents from any new bleaching technologies will need to be carefully monitored to determine their environmental effects.

Advocates of totally chlorine-free bleaching are quick to argue that the technology and its costs would be phased in over time. They say innovations will appear, increasing both TCF pulp production and quality, and bringing product prices down. This situation has led some countries to pursue a commercial agenda mandating TCF production, which would make today's high-cost TCF mills the low-cost producers, while turning currently low-cost mills into high-cost producers.

Comparing U.S. and Other Countries' Industries

For the last 20 years, the U.S. pulp and paper industry has made substantial capital investments and incurred higher operating costs to meet the environmental challenge. Other countries have not made similar demands on their pulp and paper industry. U.S. environmental investments have achieved a performance level that shows no marked difference between properly treated chlorine-bleached and nonchlorine-bleached effluents. Pulp and paper industries that have not made such investments should not be able to create a climate in which the U.S. industry has to abandon what it has done, in the name of being new and different or politically correct. These new technologies must pass the test of time; they must prove whatever benefits they may offer as the existing technology has done. This leads to my final question — what *are* the economic impacts of these changes? To put it simply, the economic costs of changing processes are significant — for industry and society.

Figure 3 shows the amount of money pulp mills have spent or will spend to go to ever higher levels of chlorine dioxide substitution to achieve specified reduced levels of AOX. The industry today is already in the 1.5 kg AOX per ton of pulp range. Companies have achieved success by foregoing increased production from current capacity. Mills have been forced to use excess recovery boiler capacity to recover solids rather than expand pulp capacity as had been planned. At "no AOX" levels, which means absolutely no molecular or elemental chlorine or chlorine dioxide is used, capital and operating costs are significant factors, but the opportunity cost is equal to the other two combined. The issue is not whether AOX can be removed. It can be if enough time and money are expended. But we have to ask how much is enough when we're siphoning off scarce capital to install technologies that have little or no environmental benefit — capital that could be used to make our mills more competitive.

In human terms, the impact of AOX reduction on potential jobs is negative. Jobs are displaced because capital that was employed with the expectation that it would yield economic benefit through expansion has now been used for AOX controls. For example, National Economic Research Associates' figures show that when AOX levels are reduced to 1.5 kg per ton, fewer than 1,500 workers are displaced. At 0.5 kg per ton reductions, up to 5,000 workers lose their jobs; at "no AOX" levels, the number of displaced workers rises to more than 36,000.

Secondary employment is also affected. Jobs in related industries are displaced because of lost actual capacity or potential capacity at local mills — victims of the multiplier effect industry has on the surrounding community. This analysis does not reflect mills operating under high variable cost structures, where adding more environmental control costs to these mills might force them to close. We don't have any data on the magnitude of such an effect, but it stands to reason that if you run a relatively high-cost mill, it will be noneconomic sooner with additional environmental costs. While other mills will make up the capacity that is lost, a resulting loss in relative worldwide competitiveness will diminish the likelihood that these offsetting capacity additions will occur in the United States.

Diminishing the U.S. Competitive Position

Competitive strength is the final component in our consideration of the economics of these changes —

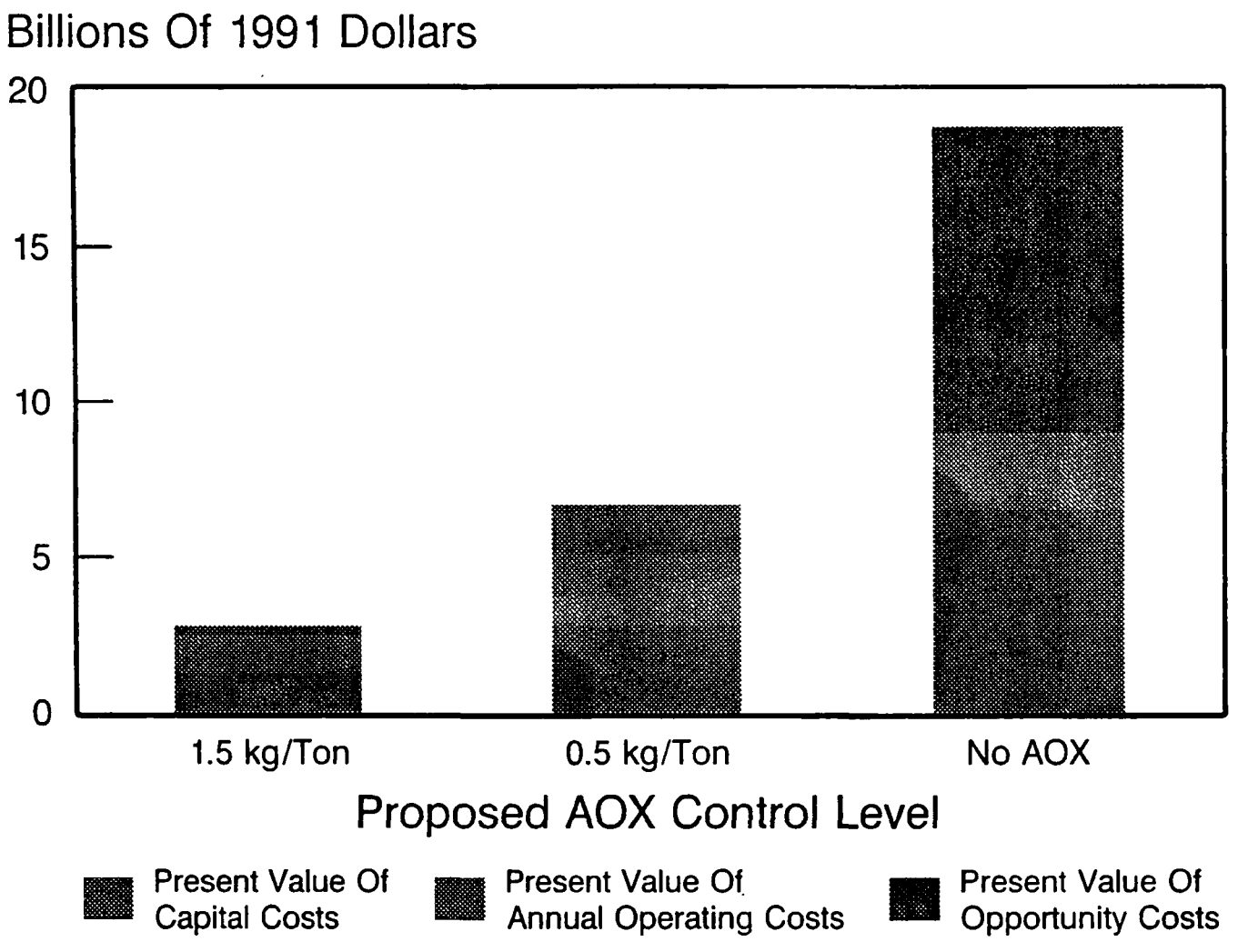

Figure 3.—Costs incurred by pulp mills to reach various AOX reduction levels.

their effects on the U.S. pulp and paper industry's competitive position. Fortune magazine recently identified this industry as one of the few U.S. industries that is competitive worldwide.

If we have to make process changes that are not warranted by sound scientific evidence, while our competitors in other countries don't, our competitive position will erode. Table 1 shows how much our competitive advantage will decline relative to some of our key competitors should U.S. pulp and paper manufacturers be required to install technologies to eliminate AOX completely. It's important to remember that the United States also imports pulp. As costs of U.S. pulp and paper increase, our domestic markets are more vulnerable to imports.

A cash flow analysis shows the impact on return on investment for a mill with AOX reduction achieved through high chlorine dioxide substitution compared with a mill trying to achieve total AOX removal (see Fig. 4). At the baseline, at a given pulp price, installing equipment to make totally chlorine-free pulp results in a reduction of 60 percent on the mill's rate of return. A 10 percent drop in the price of pulp results in a more than 40 percent reduction in rate of return at the mill that has achieved AOX reduction through high chlorine dioxide substitution versus a drop of 90 percent on rate of return for the mill trying to achieve total AOX removal. At a 13 percent drop in market pulp prices, the total AOX removal mill has no return on investment.

Prices for commodity products such as market pulp have fluctuated within these percentage ranges in recent years, adding to the risk factor for such substantial capital investments. Throughout this debate, we must remember that the marketplace is the key. Traditionally in our market economy, demand determines the product mix in the marketplace. This supply and demand equation makes the market efficient. Some interested parties see "explosive" growth in markets for TCF pulp. The facts suggest otherwise.

According to Hawkins Wright, an independent international consulting firm, TCF pulp currently accounts for less than 1 percent of the world's total

Table 1.—Competitive position of U.S. pulp producers in major export markets with and without AOX controls imposed.

IMPORTER	EXPORTER	NO CONTROL U.S. ADVANTAGE	AOX ELIMINATION U.S. ADVANTAGE	PERCENT DECLINE IN U.S. ADVANTAGE
Japan	Canada	$63	$17	73.0
	Brazil	($24)	($70)	191.7
	Scandinavia	$235	$189	19.6
Germany	Canada	$55	$9	83.6
	Brazil	($87)	($133)	52.9
	Scandinavia	$126	$80	36.5
United Kingdom	Canada	$55	$9	83.6
	Brazil	($87)	($133)	52.9
	Scandinavia	$131	$85	35.1

Costs are production costs in each producing country plus shipping costs to each major importing market. U.S. costs increase as a result of AOX reduction controls. Advantage refers to the difference in total costs for U.S. exporters to each market and the costs of each competitor. A negative result indicates a U.S. disadvantage. AOX controls reduce the advantage of U.S. producers.

pulp production. Several high-cost European sulfite pulp mills have seized the opportunity to establish niche markets in this pulp. These pulp grades are, however, inferior in quality and more expensive than those presently manufactured by the majority of world pulp producers, who utilize kraft pulping technology.

Therefore, we must be wary of attempts by special interest groups to mandate demand for one product over another. This kind of intervention throws the market off and often results in consumers not getting the kind of products they want as well as forcing the market into a high-cost mode.

If the goal is for an industry to have minimal environmental impact, the most efficient and cost-effective way to achieve that is for government environmental policymakers to set standards and guidelines — for product quality and safety, and environmental and health effects — let industry figure out the best way to meet those standards, and let the market run its course.

Look at what the U.S. pulp and paper industry has done. We've had decades of expenditures for environmental controls with corresponding environmental benefits. We've recently reduced dioxin to nonmeasurable levels in virtually all mills, with significant additional capital and operating costs. Other chlorinated organics of interest have also been reduced correspondingly. We have been successful in the area of environmental control while maintaining our competitive advantage. We simply ask that the investments we've made not be forsaken, that costs incurred have a commensurate measurable benefit, and that our relative world competitive position be maintained.

The pulp and paper industry is among the first to agree that government has an obligation to safeguard the public and set standards for environmental performance by industry. What industry is saying, however, is that we need the flexibility to meet performance standards in the most efficient, cost-effective way. In addition, the market must be

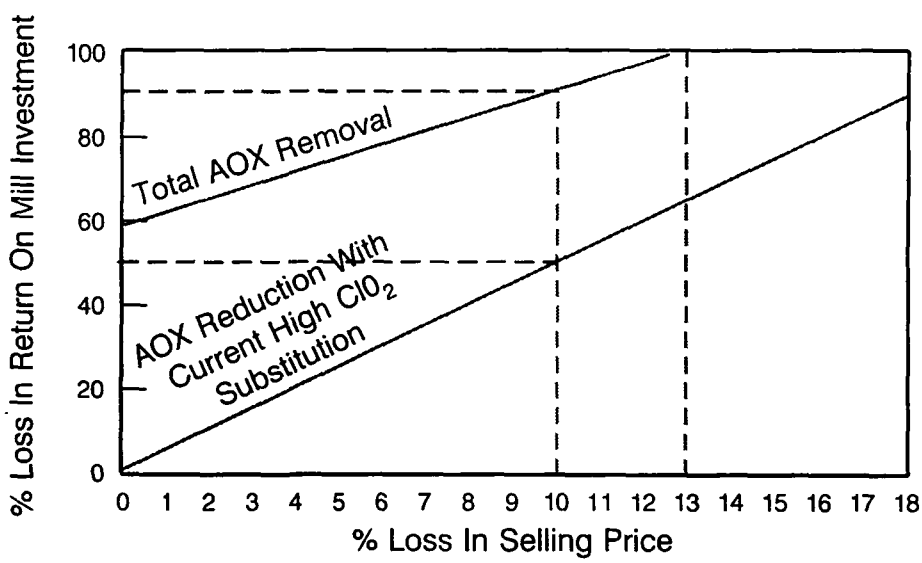

Figure 4.—Cash flow analysis: loss of ROI with pulp price reductions.

allowed to dictate changes in product mix rather than have changes mandated for it. The pulp and paper industry is meeting the environmental challenge. The important thing now is to maintain this momentum by working in partnership with regulatory and environmental organizations to ensure that environmental expectations continue to be met in the most effective way possible.

A Chlorine-free Paper Economy — Europe on the Verge

Margaret Rainey
Greenpeace Paper Campaign
Göteborg, Sweden

Greenpeace, an economically and politically independent organization working on environmental and disarmament issues in 30 countries, began working on pulp and paper issues in Europe eight years ago, highlighting the environmental impact of chlorinated effluents. The campaign has since grown to international proportions.

Paper is a unique natural product, fully biodegradable, recyclable, and made of a potentially renewable resource. Its production could be an excellent example of how clean production technologies can be used throughout a product's life cycle. Instead, shortsighted forestry practices combined with ecologically insensitive production technologies and wasteful consumption habits have made paper and its manufacture an environmental hazard.

The Greenpeace Paper Campaign focuses on maintaining forest biodiversity, reducing overconsumption of paper products, increasing paper recycling, and reducing the toxicity of pulp mill effluent. Discontinuing the use of chlorine chemicals in pulp bleaching is one of the most obvious requirements for environmentally sustainable paper production.

Chlorine-free Bleaching

Greenpeace's use of the term "chlorine-free" refers to paper that is *manufactured* without any use of chlorine chemicals; that is, none of the paper's ingredients (new pulp, recycled paper, or minerals) are processed using chlorine-based chemicals, whether inorganic (chlorine, chlorine dioxide, or hypochlorite in fiber or mineral bleaching) or organic (chlorinated dyes, wet-strength or retention agents, or slimicides). In this way the formation of anthropogenic, persistent chlorinated compounds is avoided completely. Collected paper that contains chlorine-bleached pulp should be reused but not rebleached with chlorine. The incineration and landfilling of collected paper are environmentally inferior alternatives to recycling.

In Europe, the term "chlorine-free" is applied by some representatives of the pulp and paper industry to paper manufactured with an effluent containing 0.1 kg or less of adsorbable organic halogens (AOX) per metric ton. AOX is used to measure organochlorines in pulp mill effluent. Some producers define chlorine-free as paper containing pulp bleached with chlorine dioxide. Greenpeace considers these definitions to be dishonest and misleading.

Some representatives of the pulp and paper industry do apply the same definition of chlorine-free that Greenpeace uses. Swedish pulp producers Södra Cell and three of Germany's largest paper producers — PWA, Hannover Papier, and Scheufelen — have made their position public in major marketing campaigns. Because of a demand for such products, Stora-Feldmühle, another of Germany's largest paper producers, has decided to market truly chlorine-free papers; however, this firm still retains the definition: low-chlorine is equal to "chlorine-free."

If the Swedish pulp and paper industry keeps its discharge level at under 0.1 kg AOX per ton of paper, tens of thousands of tons of organochlorines will be discharged each year under the banner of "chlorine-free" products. Most mills in Sweden are at this level today.

Organochlorine compounds are recognized as a major pollution problem because of their toxicity, persistence, and bioaccumulation properties. Many of the organochlorines identified in pulp mill effluent are highly toxic, and many of the seemingly less toxic organochlorines may be biotransformed into more hazardous compounds (Södergren, 1991).

Recent studies in Sweden and elsewhere have linked serious environmental damage to pulp mill effluents at discharge levels of about 1 kg AOX per metric ton of pulp. Effects on fish include bioaccumulation of pulp mill-specific chlorinated compounds, skeletal deformities, fin erosion, disease, reduced growth, impaired reproduction, and increased detoxification activity. Mussels and shrimp living in areas contaminated with pulp mill effluent have been found to have shell damage and impaired reproduction.

Growth damage to vegetation and biodiversity degradation have been observed in the aquatic environment near pulp mill effluent outfall. The link between chlorate discharge from pulp mills and damage to wrack (*Fucus veiculosus*), a kind of seaweed that is the most important plant in the Baltic Sea, has been verified (Södergren, 1991). Large-scale and persistent organochlorine contamination of Baltic Sea sediments has been established and linked to chlorine bleaching. It was found that a major part of the extractable organochlorine (EOCl) discharged in the Baltic since World War II still remains in the sea's sediments (Södergren, 1991).

The toxicity of bleached pulp mill effluent is made up only in part by the chlorinated fraction. Some of the negative effects described earlier can be caused or amplified by naturally occurring toxic substances in the wood, which the mills discharge into the aquatic environment in unnatural concentrations. Heavy metals and fatty and resin acids are examples of such compounds. Chlorine-free bleaching not only greatly reduces the toxicity of pulp mill effluent, it also allows for recirculation of the effluent, because corrosive by-products such as chlorides are no longer present. Since other harmful anthropogenic compounds may also form in chlorine-free bleaching processes, recirculation, or closing the loop, is a valuable way to prevent these compounds from entering the aquatic environment.

After switching to chlorine-free bleaching, a sodium-based sulphite mill in Sweden, Domsjöe (owned by MoDo), reduced its chemical oxygen demand (COD) discharge by 75 percent through recirculation. The application of recirculation to chlorine-free (and low chlorine) kraft mills is being studied intensively. Nevertheless, even if recirculation of pulp mill effluent from mills using chlorine dioxide should succeed, Greenpeace will still oppose the use of this bleaching chemical. Chlorine dioxide is a chlorine chemical and all such substances must be seen in a wider perspective, from their manufacture and transportation to use, conversion, and discharge. A large part of the chlorinated compounds end up in products and become environmental hazards when they are landfilled or incinerated. At every step, anthropogenic chlorinated compounds enter the environment.

Per-Olov Lindblad of the Swedish Pulp and Paper Research Institute widens the concept of closed-loop pulp production and recommends taking into consideration everything from "natural and human demands on forests to the final consumer's needs" (Lindblad, 1992). The only thing that would go in and out of Lindblad's closed system is solar energy and energy for warming houses and for use in other industries. All other flows would remain in the closed cycle: recycled fibers for use in new paper, energy from decomposed recycled fibers, ash containing minerals, and nutrients would be returned to the forest as alkali and useful trace elements; and the release of carbon dioxide and activated nitrogen would be in balance with the forest's ability to absorb it. Consequently, Lindblad writes:

> *At any given mill, the process could only become reasonably closed outside the mill's gates and perhaps it would be better to call it "an ecologically balanced process," where in each case the conditions are that outflow is only allowed if it can enter into a natural waste cycle in a way that is balanced and sustainable.*

This vision could be realized in part by installing a system of "kidneys" within the mill for internal purification of the waste streams. Some of the "kidneys" needed for inorganic substances, according to Lindblad, are an optimized bark boiler, a recovery boiler, and electric filtration. For organic substances, debarking and chipping optimization, straining, and delignification are examples of necessary "kidneys" (Lindblad, 1992).

Chlorine-free Bleaching's Economic Advantages

Axel Spring Verlag, a leading German publisher, conducted a survey in 1991 that showed that 46 percent of the German consumers who responded to the survey do not buy products from firms that have acquired a bad name with regard to environmental protection; 42 percent prefer to buy products from companies known for their commitment to the environment, and 89 percent were willing to accept lower quality, more environmentally friendly, paper in products such as newspapers and magazines. Respondents showed a strong willingness to pay more for magazines printed on environmentally friendly paper: 70 percent said they

definitely would do so, and 14 percent said probably (Strecker and Ernst, 1991).

European magazines are taking advantage of the growing environmental awareness. The four-color French magazine, *Maison & Jardin (House and Garden)*, added a label to the cover of a recent issue that said, in large letters, "Papier 100% Recyclé." Large paper buyers who have decided to switch to chlorine-free papers are forced to turn to European suppliers, as these products are not yet available in quantity in Canada or the United States.

Undetermined costs related to chlorine bleaching other than loss of business include lawsuits and possible liability for large-scale cleanup. Georgia-Pacific has lost two major liability suits for dioxin contamination downstream from their Leaf River plant in Mississippi. The compa y faces payments of millions of dollars and its insurer refuses to cover the claims. Still pending are an additional 159 lawsuits filed by plaintiffs who claim they have suffered harm after eating fish contaminated by dioxins from the plant. International Paper and Champion International have faced similar suits.

Mill refitting for chlorine-free bleaching consists of process changes related to both pulping and bleaching. Modified cooking, improved debarking, and improved washing are examples of changes that facilitate the switch to chlorine-free bleaching. In general the bleaching or delignification processes that are substituted for chlorine-based ones are oxygen- and peroxide-based. Ozone bleaching technology is being used to bleach kraft pulp to whitenesses that exceed 80 ISO brightness.

Refitting costs vary greatly from mill to mill. The following list shows the estimated costs of some process changes for a mill producing 500 metric tons per day:

- Modified cooking — $58 million to $67 million.
- Oxygen bleaching — $24 million to $33 million.
- Peroxide bleaching stages — $1 million to $4 million.
- Ozone (80 to 90 ISO) — $17 million.

The production costs of chlorine-free pulps are, however, higher than those of chlorine-bleached pulps, mainly because peroxide and oxygen are significantly more expensive per metric ton than chlorine chemicals. It should also be noted that at present most chlorine-free pulps are produced in batches that demand a certain recalibration of mills where chlorine bleaching is still being carried out. If a mill switches entirely to chlorine-free bleaching, lost production time and personnel costs will be avoided. At present chlorine-free kraft pulp costs about 15 percent more than the chlorine-bleached equivalent.

If customer demands for unnecessarily high paper whiteness were reduced, the amount of bleaching chemicals needed would be reduced accordingly. This reduction would save chemicals and energy and help close the price gap between the two kinds of pulp. Mills would save on bleaching chemicals, and they would not have to invest in expensive technology, like ozone bleaching, to bleach pulp to high whiteness levels. Many paper producers agree that 85 ISO pulp is sufficient for nearly all paper grades. Chlorine-free pulp at significantly lower whitenesses (70 ISO) has been used with success in light-weight coated papers.

British Columbia, Canada, became the first government entity in the world to set a date for a total ban on chlorine bleaching: 2002. Ontario is considering following suit. A May 1990 draft recommendation from the German government stated that all use of chlorine-bleached fibers should be avoided. In June 1991, the Norwegian minister of the environment called on the other Nordic country environmental ministers to join him in a ban of all chlorine-bleaching agents by 1999. The Swedish government has stated that the discharge of all substances from the pulp and paper industry that are toxic to the environment should end by 2000.

Chlorine-free Mills and Their Customers

The amount of chlorine-free pulp on the market has increased dramatically during the last year. Of Sweden's bleached chemical pulp capacity — about 5 million metric tons — 70 percent could be produced chlorine-free if the market demanded such quantities. During 1992, about 10 percent of the Swedish bleached kraft-pulp production will be chlorine-free. In Finland, about one-third (or 1.4 million metric tons) of the chemical pulp capacity can now be produced chlorine-free. The entire German production of sulfite chemical pulp is already chlorine-free. A new chlorine- and sulfur-free mill, using the Organocell® technology, will be completed in Germany within the year. It will have a capacity of 150,000 metric tons.

Low chlorine and chlorine-free pulp production has led to a dramatic decrease in the use of chlorine gas in Sweden. In 1970, 230,000 tons of chlorine gas were used for pulp bleaching; in 1991, 33,000 tons were used; and during 1992, 5,000 to 10,000 tons will be used. During 1993, the use of

chlorine gas by Swedish pulp mills will cease entirely.

Södra Cell, the largest market pulp producer in Europe, announced recently its intention of making its entire capacity, about 1 million metric tons of bleached kraft pulp, available chlorine-free. The company has installed ozone bleaching at its Mönsterås mill (capacity 335,000 metric tons), with production slated to begin in September 1992. By the end of the year, the Mönsterås mill should be totally chlorine-free. Södra is producing chlorine-free softwood kraft now at 80-plus ISO. Several other mills in Sweden and Norway have plans for installing ozone bleaching technology.

Consumer demand for chlorine-free products has been mostly felt in Europe, where the four major pulp and paper buying countries together import more than 8 million metric tons of pulp, or 10 percent of the world's annual production. Bleached chemical pulp imports in 1991 to some European countries were reported as follows:

- Germany — 3,075 million metric tons;
- France — 2,091 million metric tons;
- UK — 1,401 million metric tons; and
- Italy — 1,785 million metric tons.

The printing and writing sector uses 40 percent of the global production of pulp and paper and 80 percent of the chlorine-bleached pulp. In this sector, especially in magazine papers, the demand for chlorine-free paper is very strong.

Each year Germany uses 2 million metric tons of light-weight coated magazine paper. Greenpeace chose to work with this market in particular. In March 1991, we released *Das Plagiat* ("The Plagiarism"), a spoof on one of Germany's largest weekly newsmagazines, *Der Spiegel*. The most important difference between *Das Plagiat* and *Der Spiegel* was that the Greenpeace magazine was printed on the world's first chlorine-free light-weight coated magazine paper. The *Plagiat* paper was about 2 percent less white than the *Spiegel* chlorine-bleached paper. We wanted to demonstrate high quality, four-color printing on a paper that was a little less white. The German paper industries and magazine publishers' branch organizations reacted immediately. In a joint press release, they announced that they would use chlorine-free papers as soon as they were made commercially available.

Shortly afterward *Der Spiegel*, with a circulation of about 1.2 million, stated its intention to switch to chlorine-free paper as soon as it was made available. Now, one year later, *Der Spiegel* manages to print an average of 30 percent of each magazine on chlorine-free paper. *Der Spiegel* finds the two papers so equivalent that they do not hesitate to use both in the same issue. Other magazines, such as *GEO, SPORTS,* and *ART,* produced by Gruner & Jahr, *Der Spiegel's* publisher, are now chlorine-free.

Stern, another of Germany's largest weekly newsmagazines with a circulation of about 1.3 million, has changed much of its super calendar (SC) magazine paper to chlorine-free. Austria's major news weekly, *Profil*, changed its SC paper to chlorine-free in May and stated in an editorial, "This (paper) is at present somewhat more expensive, but the company deemed this contribution to environmental protection worth the sacrifice."

In January 1992, after receiving 22,000 post cards from Greenpeace supporters demanding chlorine-free paper, *TIME* magazine announced in an editorial that "Most of our paper suppliers are far along with their plans to eliminate chlorine-bleached pulp. We will use this alternative paper as soon as it is practical to do so."

McLean-Hunter, Canada's largest magazine publisher, announced in July 1991 that it would switch to chlorine-free paper in its more than 200 magazines as soon as the paper was made available. The largest magazine publisher in Quebec, Publicor, has also announced that it will switch to chlorine-free paper. The largest chain of copying centers in the United States, Kinko's, has also stated its intention of switching to chlorine-free and recycled papers.

The annual catalog published by the furniture retailer IKEA is one of the largest color printing jobs in the world, demanding 40,000 metric tons of paper and read by millions of people each year in 25 countries. The recently distributed 1993 IKEA catalog is printed on chlorine-free 51-gram light-weight coated magazine paper, which is also guaranteed not to contain pulp from old-growth forests. In addition, IKEA reviewed all glues, lacquers, and printing inks used in the catalog that could disturb recycling.

The changes in IKEA's catalog paper were worked out in cooperation with Greenpeace. By systematically examining the environmental aspects of its paper, IKEA managed to avoid contributing to some of the most serious environmental problems caused by the pulp and paper industry. Because of reduced paper prices, the 1993 catalog did not cost more than in previous years, even though the new paper actually represented an extra expense. IKEA was, however, willing to pay more for a more environmentally sound catalog. The paper suppliers of the IKEA catalog were all European corporations.

The chlorine-free light-weight coated paper meant a marginal reduction of whiteness, but no adjustments were necessary in the printing. The bulk and printability were equivalent to those of chlorine-bleached paper and the opacity was somewhat improved. The catalogue was printed simultaneously by most of the major printers in Europe. One of the largest, Germany's Gruner Druck, found that the chlorine-free paper supplied by IKEA "posed no unusual problems in terms of printability, web breaks, or quality which originated and/or could be traced back to the use of chlorine-free pulp in the paper" (K. Veit letter to Greenpeace, August 14, 1992).

The next logical step is for magazine and other paper products to contain a high recycled fiber content. There are super calendar papers currently available that consist of 40 percent postconsumer recycled fiber. Several pulp and paper industries intend to build super calendar paper machines in the near future that can accept a high percentage of recycled fibers. Japanese manufacturers have come far with postconsumer recycled-fiber content in lightweight coated papers reaching 80 percent. Chlorine-free light-weight coated papers containing as much as 50 percent recycled fibers are being developed in Europe and should be on the market in the near future.

Conclusion

Greenpeace estimates that in the near future it will be difficult to sell pulp bleached with chlorine chemicals, or paper containing such pulp, in such European markets as Germany and the United Kingdom. Two of the remaining obstacles to a totally chlorine-free paper economy in Europe are

- the unethical selling of low-chlorine bleached pulps as "chlorine-free," thereby undercutting the higher price of truly chlorine-free pulps; and
- the lingering unwillingness of large pulp buyers to pay more while simultaneously accepting lower whiteness levels.

Consumer awareness will put a stop to false marketing strategies. Products like the IKEA catalog show that it is possible to use pulps at lower whiteness levels and achieve good results. The higher price of chlorine-free pulps must be viewed in relationship to the inestimable environmental costs of chlorine bleaching and open-loop pulp production.

The goals for environmentally sustainable paper production are to

- maintain forest biodiversity, for example, by stopping the use of old-growth forests;
- achieve a totally chlorine-free pulp and paper industry;
- remove all remaining toxics from the effluent; and
- increase recycled fiber use.

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Performance and Cost Considerations in Pollution Prevention Practices

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Recycling and pollution prevention are not new or novel ideas in our industry. They have been batted around, to one degree or another, since its beginning more than 300 years ago, driven by changing economics, technology, and recently, societal values. To illustrate my point — I started my career in 1947 in a recycling paperboard mill that was then 50 years old. This supposed "temporary" mill job, which paid me $1.13 an hour when I started, lasted 15 years and paid for my schooling in chemical engineering. I mention this background to establish my qualifications for the observations that follow.

The industry recognized the need to better understand water pollution in 1943, when it established the National Council for Air and Stream Improvement (NCASI) — a full 27 years before the creation of the U.S. Environmental Protection Agency. The organization added oversight of air improvement in 1956 and solid waste in 1968. NCASI is still the industry's primary research arm in these areas.

Forty-five years ago, pollution prevention was limited by the industry's technical inability to identify, control, or prevent the many undesirable emissions, discharges, and solid wastes that we have since defined. At that time, recycling was driven by economics, which made waste paper — in a variety of grades similar to that which is recycled today — more economical to use because it was readily available in urban areas. Virgin pulp was more costly to use because it was produced in rural areas and included freight costs.

My experience has made me keenly aware of the limitations of recycled products in terms of product quality, economics, and pollution control. In earlier days, we used 450 tons per day of waste paper to gain 300 tons of pulp. The remaining 150 tons went to the sewer or the city dump. Though we have progressed technologically, similar ratios apply today to recycling.

The postwar period brought population growth, economic growth, and expanding technology to many industries, ours included. A higher living standard followed, precipitating many changes in attitudes and values. Those of us who were children of the Depression began to shed the economic insecurities gained during those years of deprivation. We began to appreciate and demand a better environment.

One incident from 1952 illustrates this change in values. I was plant engineer at the Chicago recycling mill at the time, and I received a phone call from Mr. McCormick, owner of the *Chicago Tribune*, complaining about the dark smoke from our coal-fired boiler stack. Twenty years before, at the height of the Depression, smoke from a factory stack in Chicago was a welcome sign of work and a paycheck.

The paper and pulp industry was in the forefront in responding to changing values — we promoted recycling, pollution prevention, and technological change in an aggressive and constructive way. When I joined my current employer, Potlatch Corporation, in 1962, it was a company engaged in growing trees to produce lumber and plywood and using residual wood waste to manufacture bleached kraft pulp. Our company initiated the process of using scrap wood for bleached kraft in Lewiston, Idaho, in 1950. It was a much better alternative to burning wood waste, which was the common practice, and landfilling was not a practical solution even then in Idaho.

Potlatch's pioneering efforts in the use of wood waste were accompanied by evident opportunities for reducing odor and particulate and other discharges, while simultaneously improving product quality and lowering costs. In 1960, market

demand for improved product quality had led to a change in the bleaching process from CEHEH (chorination-caustic extraction-hypochlorite reaction-caustic reaction-hypochlorite) to CEHED (first four stages, then chlorination with chlorine dioxide). The change also resulted in reduced chemical costs and lower biological oxygen demand (BOD) loadings.

Incidentally, Potlatch is a relatively small company — 18th in size in the U.S. paper industry — in a highly capital- and labor-intensive business. For that reason, we have always considered it in the best interest of our employees and investors to stay modern and cost-competitive, but we have been unwilling to "bet the company" on unproven processes or untested markets. We have followed emerging technologies, employed both mill technical resources and our own research and development activities, and used the increased knowledge to guide capital improvements and address market concerns. We've followed the totally chlorine-free bleaching processes and believe we can learn much from them. But we also find no evidence that they are more environmentally friendly than the process they would replace. They may, in fact, be less environmentally friendly because they generate aldehydes and ketones.

Since the early 1960s, the company's Idaho operations have been modernized and have grown threefold in response to the availability of, and need to use, waste wood from the region's forest products producers. We now operate a state-of-the-art bleached kraft mill with 100 percent forest and sawmill waste wood. We have just completed a 10-year, multiphased modernization that culminated this summer in the installation of a new bleaching operation featuring modern pressure washers, high-consistency oxygen delignification, 70 percent substitution of chlorine dioxide in the chlorination stage, followed by an oxygen-enhanced extraction stage, and a final dioxide stage.

These changes, too, were motivated by the need for improved product quality and competitive cost structures. But they have also resulted in less dioxin in our product and effluent. Our effluent adsorbable organic halogens (AOX) are well below 1.5 kg per ton and our secondary pond BOD loadings have dropped by 60 percent. Chloroform generation has dropped by 70 percent. None of these were major environmental issues when the technology was chosen for facility modernization in 1981.

Potlatch's second bleached kraft mill, built in Arkansas in the late 1970s, has made similar changes. With increased washing efficiencies, the elimination of petroleum-based precursors, added oxygen enhancement in the extraction stages, and more than 70 percent substitution of dioxide in the chlorine stage, we have today effluent and products with nondetectible dioxin and adsorbable organic halogens of less than 1.5 kg per ton.

We have a third bleached kraft mill in Cloquet, Minnesota, and we have recently received a permit to modernize and expand it over the next five years. When the modernization is complete, the technology installed there will produce pulp for high-quality printing papers that will be free of elemental chlorine.

These changes of process and equipment epitomize the essence of pollution prevention rather than "end of pipe" treatment, and are typical of the approach Potlatch is taking on several fronts. We have made significant strides, for example, in energy efficiency by installing huge multifueled boilers at our Idaho and Minnesota pulp mills and smaller units at our wood products operations in Arkansas and Minnesota. These boilers allow us to use regionally generated wood wastes as a fossil fuel substitute and, in combination with cogenerated electricity; have increased our energy self-sufficiency more than 75 percent. This substitution not only reduces undesirable emissions; it also conserves nonrenewable resources.

Pollution prevention can also be achieved through smaller, less obvious operational changes that contribute to both environmental and economic efficiency. To that end, we have attempted to build the concept of pollution prevention into our corporate culture by encouraging employee involvement at all levels. In Idaho, for example, our hourly and salaried employees have established a Waste Reduction and Pollution Prevention committee, the WRAPP team. Its goal is to expand the pollution prevention ethic throughout the operation.

Something as simple as conserving water wherever possible can add up to significant savings and, at the same time, cut emissions. The WRAPP team has suggested ways to reduce water use by thousands of gallons a day in Idaho. What we don't use we don't have to treat.

Pollution prevention makes economic and environmental sense, and we're proud that our processes and products are environmentally safe and friendly. But there are many trade-offs. Potlatch plans to continue its commitment to improved pollution prevention in cooperation with the regulatory agencies, while playing a constructive role in maintaining the clearly superior environmental record and competitiveness of the paper industry in this country.

Panel 3:
Technical Perspectives — Performance and Cost

Question and Answer Session

■ **John Festa,** *American Paper Institute:* Margaret, in your handout you say that recent studies in Sweden have linked pulp mill effluents containing absorbable organic halogens to serious environmental damage. And you mentioned a conference in Sweden last November that I also attended. Now, if I'm not mistaken most pulp mills in Sweden discharge into the Baltic Sea or into rivers or tributaries that flow into the Baltic. At the conference, the one you mentioned, a Swedish EPA publication was circulated that indicates that the Baltic Sea is pretty unique from an environmental standpoint.

Let me read from the Swedish pulp publication, if you'll bear with me.

The Baltic Sea is particularly vulnerable to the toxic organic pollutants released by industrial society. There are several reasons why this is the case. The Baltic is the final destination for discharges and land runoff from a cluster of highly industrialized countries, yet it is little more than an inlet, a virtually enclosed sea. It's sole link with the world ocean consists of three straits at its southwestern end which permit only limited water exchange. . . . It is also a cold sea with a short reproductive season. The Gulf Botany, the Baltic's northern flank is frozen over from December to May. Only a few different species thrive in these chilly brackish waters, making food chains extra sensitive to disturbance.

I think one needs to be very careful in extrapolating data from the Baltic Sea to other water bodies that are not comparable. In this country, the Paper Industry's National Council for Air and Stream Improvement, has conducted experimental stream studies for over 15 years and in these studies fish have been exposed to bleached kraft mill effluent at different concentration levels. Yet, to date, the studies show normal growth, survival, and reproduction in fish exposed to well-treated mill effluent. In addition, histopathology has not shown any lesions in the fish.

■ **John McGlennon, Moderator:** Are you leading up to a question, or are you about to complete your comment?

■ **John Festa:** It's a comment, but I think it's well worth making. The National Council has published the results of its studies recently, and if you're interested I have copies of those papers. In Sweden, if I'm not mistaken, less than 50 percent of the pulp mills have secondary treatment. In this country, virtually all pulp mills have secondary treatment. That makes a big difference. Thank you.

■ **Margaret Rainey,** *Greenpeace:* For your information, 30 percent of the kraft mills have secondary treatment. But anyway, what they have emphasized are internal process changes, not external treatment. As far as not extrapolating results from the Baltic to use on other pulp mills, some of the studies presented here are lab studies. And labs are the same everywhere, I hope. I'd just like to say that I think this is a very important discussion and I hope that we can have it sometime. I feel that people aren't very happy about discussing it right now. Yes, next year, same time, same place, let's talk about it. I'll give a presentation.

■ **John Festa:** You're right that this isn't the time or the place and the forum hasn't really been set up for the discussion. But it's clear to me that everybody's dying to talk about it.

■ **Mark Floegel,** *Greenpeace:* Briefly, as an aside to John. If we're talking about studies, there is one that was not funded by the pulp and paper industry. In fact, it came from the International Joint Commission, an independent body, whose members are appointed by the United States and Canada. Their biannual report, issued just a few months ago, recommends that all industrial chlorine discharges to the Great Lakes be discontinued. You may want to take a look at that.

Out of deference to Mary Ellen Weber and some discussions that we've had about how many angels can sit on a pin, I'm not going to address any of what I consider to be the egregious misrepresentations by Kip Howlett in his presentation. However, let me ask him about money, which I think we are allowed to talk about. In your presentation, Kip, you talked about the jobs that you feel have been lost because the industry has had to invest in environmental technology. Now, of course, my experience with corporations is that this money probably wouldn't have gone to jobs but to executive bonuses. But you're theorizing that jobs could have been created.

I want to get your feedback on some of the real numbers that Margaret referred to. The fact the Georgia-Pacific has now lost two lawsuits in the state of Mississippi with total damages of, I believe, $3.25 million, because of discharging chlorine-based chemicals in the Leaf River Mississippi pulp mill. In addition to the two suits that have been lost already, 8,000 others pieces of litigation have been filed. Your insurance carrier, Aetna, has declined to pay for these damages and your own shareholders are suing Georgia-Pacific because you failed, allegedly, to file this litigation in your SEC filings. These are real dollars and this does not even begin to count what's going on in the fishing industry in coastal America as a result of toxic pollution from a variety of industries. But, at least in terms of these lawsuits, the courts have directly tied your use of chlorine to property damage, trespass, and nuisance to property owners downstream. So we're talking about real dollars. That money represents income that has been lost, jobs that have been lost, hardships that have been endured in a monetary sense. We're not talking about the environment or health, we're just talking about the economy. Could you comment on that?

■ **John McGlennon:** I would like to remind the speakers that we are still talking about pollution prevention technology and alternatives to achieve pollution prevention from a technical point of view, but if Kip wants to comment on this, he's welcome to do so.

■ **Clifford T. "Kip" Howlett,** *Georgia-Pacific Corporation:* Well, I want to correct some misstatements and mischaracterizations. First, with regard to the shareholders, that suit was filed by the same plaintiff lawyer in Mississippi who filed all these other lawsuits.

■ **Mark Floegel:** I believe that's incorrect. It was an Atlanta law firm that brought the shareholder's suit.

■ **Clifford Howlett:** Well, if you look at all co-counsel, you'll discover that there's a synergy there. Second, I think that if we want to have a discussion about the current litigious nature of society in the United States, that is also best left for another symposium. I would simply point out (1) that both cases are on appeal and (2) that the mill, from the date that dioxin was discovered until now has gone to 100 percent ClO_2 substitution. Over the last few years, there has been both no measurable dioxin and, according to the latest data, no measurable chlorinated phenolics in that mill effluent.

I don't want to try these cases here, but so the audience will understand, the first case was trespass. It dealt with the allegation that dioxin had found its way onto the property of riparian landowners. The judge in that case did not allow the introduction of any data to show that actual dioxin levels were not present in the properties involved. The second case was a fear case, and that case, frankly, got way out of control. It may be some time before we figure it out — in part because of witnesses, in part because of problems with rules of evidence. Both cases are on appeal. The bottom line is that this mill, in fact, has no dioxin or chlorinated phenolics. We've made the changes, and we were one of the first mills in the country to do so.

■ **Mark Floegel:** I, too, would have liked to stay on technical things, but it was Mr. Howlett who took us off into jobs. From a legal point of view, please, just one last point.

■ **John McGlennon:** This discussion could go on and on. You can still have it, but I'm not sure it's constructive to take up the time of 300 people to listen to it.

■ **David Bailey,** *Environmental Defense Fund:* Maybe I can keep us on track in terms of pollution prevention. I accept the fact, as I'm sure most of the paper industry does, that both sides are going to

make claims and statements that they believe to be correct and true, which are, in fact, debatable. But I would like to focus on one point and ask whether it will be in the speakers' papers or in the proceedings when they're finally published. Or, perhaps, Mr. Congreve or Mr. Howlett would like to comment at this time. I hear repeatedly and have heard for the last several days that there are no detectable levels of dioxin in "x" company's effluent or process. I'd like to know if there's any commonality about what level of detection we're talking about here. Are you familiar with the level of detection that these statements refer to? Because I think that does relate to whether we are having pollution prevention.

■ **Clifford Howlett:** Only one or two commercial labs in the country are really in a position to do this kind of testing. I believe the detection limit in water effluent is down to about 10 parts per quadrillion.

■ **David Bailey:** Just as a suggestion then, or a brief comment. It really doesn't help the argument, I don't think, to say that you're below 10 parts per quadrillion because that number still doesn't answer the question of where you are in relation to where you need to be. It doesn't say where you are vis à vis a standard. So, I would be a little cautious about those claims. If anyone has done better than that on an experimental basis, or whatever, and can compare their effluents to lower levels of detection, that might have more relationship to the standards that are flying around right now. It might be helpful to everyone.

■ **Gayle Coyer,** *National Wildlife Federation:* I'd like to ask for a few points of clarification and one of them refers to the exact same question that was commented on by the previous speaker: the levels of detection issue. Mr. Howlett's talking about a detection level of 10 parts per quadrillion. Mr. Congreve, can you give us this same information? What is your level of detection?

■ **Richard Congreve:** Ours is less than 2 parts per quadrillion.

■ **Gayle Coyer:** Less than 2 parts per quadrillion. Since it is obvious that the level of detection is a moving level right now, I would like to request that all speakers from now on define what level of detection he or she uses. I think this clarity would help our discussion a lot. The second thing, and again, I'm not going to debate the toxicity information here. But I would like to know from Mr. Howlett if he would give us the citation for the expert panel of international scientists who conclude that there's no difference in toxicity. I think it's a very important reference.

■ **Clifford Howlett:** Yes, it's published.

■ **Gayle Coyer:** My third point has to do with your charts. I am trying to understand your graph about the jobs that will be lost to the different levels of AOX reduction. Your statement was that the amount of money used for AOX reduction stands for jobs that won't be created. Is that what you were signifying?

■ **Clifford Howlett:** They're not available. The investments that have been made over the last 5 or 10 years are an example of what is recoverable. You may make the investment and deliberately oversize with the anticipation that down the road you'll add another machine and use the additional capacity. That possibility factors into the decision that you make in asking your board of directors to approve the capital expenditure. But to retrieve solvents for achieving the kind of AOX and dioxin reduction levels that the industry has experienced requires that you absorb some of that planned capacity addition. That capacity addition is real; those are real dollars invested and real capacity that's lost. In addition, there are secondary employment impacts from the foregone production that I discussed in those four slides, the three maps and one chart.

■ **Gayle Coyer:** So you actually looked at what the planned capacity addition was in different mills in the United States and worked from a planned capacity addition statistic?

■ **Clifford Howlett:** With what was in the mills. This data is real world data.

■ **Gayle Coyer:** This planned capacity is currently not being used and you're saying that the reason it's not being used is because the additional capacity may be required to go into further AOX reductions?

■ **Clifford Howlett:** It could be, or it could be used as part of the process control to reduce the level.

■ **Gayle Coyer:** The relationship may not be quite that simple. A number of other factors may influence what those alternative investments might be. I would also like to submit that, at least to some extent, tougher and stronger environmental control regulations have kept the industry at a globally competitive rate with modernizations on line.

■ **Clifford Howlett:** I don't disagree with that analysis. The key here is that the economic viability of the industry enables you to make those kinds of

environmental investments. They go hand in hand, and they are not in conflict with each other. In fact, I think they mutually support each other.

■ **Richard Congreve:** I disagree with Kip a little. I don't agree that we've been forced into these so-called major changes because of the regulations. What we did in our mill in Lewiston, Idaho, was a process totally conceived in 1981 but it meets every regulation that has been implemented since that particular time. So I do believe there are a number of mills in our industry that have aggressively improved their prevention pollution efforts, and not because of regulations, as inferred.

■ **Steve Levitas,** *Environmental Defense Fund:* If I could ask a follow up question to Mr. Howlett. Did you do that economic analysis yourself on the cost of AOX reductions and if so, can we get a copy of the background research that produced those slide?.

■ **Clifford Howlett:** Yes, we'll include that in the report.

■ **Steve Levitas:** If I could make a brief comment. I think everybody recognizes that there are profound differences of opinion on how pollution affects health, on the performance of alternative technology, and on economics. The question for all of us is how we're going to make constructive progress. One way would be to debate these issues indefinitely. I would suggest, however, that debate has not been a productive way to deal with environmental conflict in the past, and it's not going to be productive now. Indeed, I think the orientation of this conference reflects the hope that there's a different way to proceed. Why don't we sit down and figure out ways to address the performance and economic issues in a way that will meet the industry's and society's needs. Mr. Howlett, I thought you did an excellent job of charting out exactly the wrong directions for making progress, and I think we ought to try to get on track.

■ **Jessica Landman,** *Natural Resources Defense Council:* My question is also for Mr. Howlett. You stressed in your presentation the importance of providing exactly the product your customer wants and not having the product quality, its type, or performance dictated by the government. That is, you want to satisfy the market that you believe exists. In light of that I wanted to ask you to tell us, if you would, what was behind the memorandum that Georgia-Pacific sent to its customers, informing them that chlorine-free products are inferior and you will not be making them available to your customers even if they have an interest in buying them? This memo was subsequently reprinted in a trade journal.

■ **Clifford Howlett:** The letter that we sent to our customers was based on using a high chlorine dioxide substitution process that achieves nonmeasurable levels of dioxin in the effluent, recognizing that this result is nonmeasurable given the current ability of commercial labs to measure dioxin. First, we are not committed to the abandonment of the chlorine dioxide investment that we have made. Second, if we are going to look at totally chlorine-free technologies, it is our understanding that they have not yet been commercially approved, and we are not in a position to offer pulps made from those processes to our customers at this time. That was just the point of the letter.

Costs and Benefits of Various Pollution Prevention Technologies in the Kraft Pulp Industry

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Kraft pulp is manufactured in the United States from nearly all commercially available wood species. About 55 million tons per year are manufactured, 30 million of which are bleached and used mostly for printing and office papers and tissue products. Some kraft pulp is exported, and significant quantities are imported, mostly from Canada and South America. Pulps manufactured by sulfite, mechanical, and deinking processes are being used to a modest but increasing extent to replace bleached kraft pulp in certain markets.

The manufacture of bleached kraft pulp is a major but not dominant source of water pollution in the pulp and paper industry. With respect to pollution prevention measures, bleached kraft mills in the United States range from the best in the world to about average, compared with the other pulp producing countries. The characteristics of mill effluent discharged in this country are probably somewhat better than average, since 97 percent of our bleached kraft mills have secondary effluent treatment. In other pulp producing countries, from 50 to 100 percent of mills have secondary treatment.

This paper discusses only the manufacture of paper grade bleached kraft pulp, for market or for on-site use in an integrated paper mill. The International System of units (SI, Systeme International) is used throughout, unless otherwise noted.

Environmentalists have focused their attention on the kraft pulp bleaching processes because so many of the most widely known, persistent pollutants discharged by the pulp and paper industry originate in that part of pulp manufacture. But the prebleaching pulping processes are also significant, and many measures that reduce or prevent the formation of pollutants in the bleach plant are implemented upstream in the pulping operations.

An Example Mill

Mills in the United States vary from large, simple modern mills with one single production line manufacturing one single product to complex multiproduct, multiline mills. In the 90 existing U.S. bleached kraft mills, pulp capacities vary from about 300 tons per day to 3,000 tons per day.

References to capital costs in this paper are all for retrofitting pollution prevention technologies to a 1,000 air-dried ton per day, single line mill using typical 1970s technology. This technology includes wet debarking, traditional batch digester cooking, a brown stock washing system operating with 20 kilograms per ton of salt cake loss, and a bleach plant with 10 percent chlorine dioxide substitution. The mill process in Figure 1 operates to this description, except that an oxygen delignification stage and a condensate stripper have been added. Figure 1 also incorporates a continuous digester instead of a batch system.

The effluent discharged to the biological treatment system from such a mill would have a biological oxygen demand (BOD) of 35 kilograms per ton and 5.3 kilograms of adsorbable organic halogens (AOX) per air-dried ton of pulp.

This base case mill has not implemented any of the pollution prevention technologies discussed in this paper, whereas most mills have implemented some, and a few mills have all feasible pollution prevention technologies in operation. The capital costs, operating savings, and attainable reductions

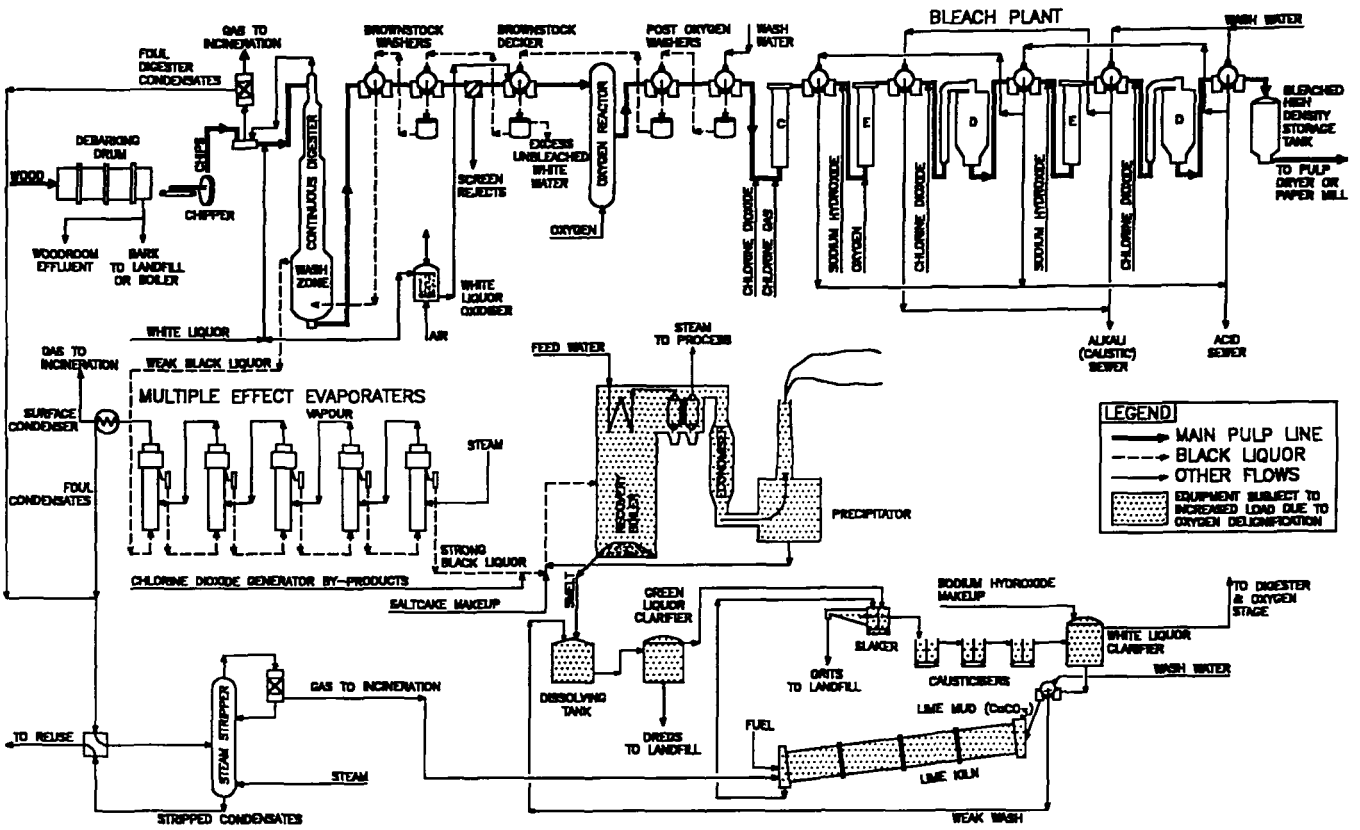


Figure 1.—Example of a kraft mill flowsheet with oxygen delignification.

in effluent discharges in typical U.S. mills will generally be lower than the data presented here, because of the prior implementation of pollution prevention technology.

Current pulping and bleaching technologies have been described by many authors, including Kocurek (1986-89) and McCubbin et al. (1991).

Available Technologies

There are many technically proven ways of reducing or eliminating the formation of pollutants during the manufacture of bleached kraft pulps. Much attention has been focused on the technology and design of new mills. One can expect, however, that only a few new bleached kraft mills will be built in the United States during the next decade. The key environmental, technical, and financial challenge is to define and retrofit the most appropriate environmental protection technology in the 90 existing bleached kraft mills.

The interrelationships among available pollution prevention technologies are complex, and the optimum selection for each mill depends on the site, the product specifications, and most of all, on the type, obsolescence (or otherwise), and general condition of existing systems. Unless otherwise noted, the technologies discussed herein have been proven in mill service for at least a year, and are available from several established, competitive vendors of pulp processing equipment and systems.

Dry Debarking

Logs must be converted to chips to feed kraft digesters. Prior to this, the outer bark and dirt contamination must be removed. The process for carrying out this operation is termed debarking and may be a wet or a dry process. The wet process causes resin acids and other, mostly nonpersistent, toxic and highly colored substances to leach out of the bark and be discharged with the effluent.

Dry debarking is more desirable environmentally than wet debarking and has been almost universally adopted in new mills and modernization projects for wood preparation systems built since the mid-1970s. The industry is moving steadily toward dry debarking, since the proportion of wood now purchased in the form of (dry debarked) chips from sawmills is increasing.

The cost of a new dry wood preparation system is very similar to an older design wet system. Conversion of a wet system to dry operation for the example mill would cost between $10 million and $20 million, while the annual operating costs would probably be little changed.

Referring to Figure 1, the debarking drum would be replaced by either a dry drum or a multi-

knife mechanical chipper, and the woodroom effluent flow would be eliminated. This change would reduce the contribution to mill effluent by the wood preparation department to nearly zero, a reduction in the mill effluent flow by as many as 25 cubic meters per ton of pulp. The BOD of the untreated effluent would also decrease by several kilograms per ton depending on initial conditions. Since biological treatment systems are quite effective in treating such wastes, the improvement in final effluent quality would be modest. Obviously, dry debarking would be essential in a zero effluent mill.

Extended Cooking

In conventional kraft cooking, the complete charge of chemicals (sodium hydroxide and sodium sulfide) is added to chips simultaneously, leading to high concentrations that gradually fall off as the process proceeds. The wide range in chemical concentration leads to aggressive chemical action at the beginning of a cook and very gentle pulping at the end. In the 1970s, the Swedish Forest Products Laboratory developed the concept of "modified" cooking. (Hartler, 1978; Teder and Olm, 1980). The approach was to level off the alkali concentration throughout the cook so that the initial action would be less aggressive, and to allow additional lignin to be removed in the latter stages of the process.

This process has become more popularly known as "extended cooking," and in the late 1980s, vendors of both batch and continuous digester systems developed practical, commercial kraft pulp cooking systems based on Hartler's modified cooking concept. MacLeod (1992) and Whitley et al. (1990) have presented recent updates on extended cooking technology.

In the Modified Continuous Cooking (MCC®) process, the cooking liquor (white liquor) is added at several points, instead of only in the chip feed to the digester as is indicated in the conventional continuous digester shown in Figure 1. In many current continuous digesters, the pulp is washed with hot black liquor in the lower "wash zone" of the digester. Several mills have added white liquor to this wash circuit, and installed heat exchangers to raise the temperature to levels normal for cooking pulp. This is known as the Extended MCC (EMCC®) process, and is the variation of most interest for retrofitting to existing operations.

Several mills using their own engineering knowledge have modified their continuous digesters to take advantage of Hartler's modified cooking concepts. Kamyr, Inc., the only United States supplier of continuous digesters, also undertakes conversions routinely.

■ **Modified Batch Cooking.** For batch digesters, implementation of extended cooking technology also involves maintaining liquor concentrations at a more uniform level throughout the cooking cycle. Patents were granted to Fagerlund, and the success of the Modified Batch Cooking (MBC) process was reported by several groups (Andrews, 1989).

The MBC process involves saturating the chips with warm black liquor under pressure to improve air removal and liquor penetration, creating more uniform cooking conditions. The warm black liquor is displaced with hot black and white liquor and the chip charge is then cooked. After cooking, the hot (spent) black liquor is displaced with wash liquor from the first brown stock washer, and stored to provide the hot black liquor for a subsequent cook. The process was developed to reduce steam requirements, and is technically quite effective.

MBC equipment is much more complex than conventional batch digesters; it includes several pressure vessels at least as large as a digester and extensive piping, valves, and control systems. The complexity increases as the number of digesters increases. Although the basic cycle is simple in concept for a single digester, it requires careful scheduling to operate several digesters simultaneously, even in theory. In practice, major production losses in process conditions and pulp quality can occur because of equipment failure and operator error.

Two well-established vendors offer MBC systems commercially. Beloit, Inc., markets the Rapid Displacement Heating (RDH) System and Sunds Defibrator, Inc., markets the SuperBatch™ System. Extended cooking to kappa number levels of 15 to 18 for softwood and 8 to 10 for hardwoods using the rapid displacement heating process were described by Andrews (1989). Somewhat similar results were reported by Pursianen et al. (1990) using the SuperBatch™ process in two Scandinavian pulp mills.

Current extended continuous cooking technology will allow pulps to be produced at kappa numbers of under 10 for hardwood and kappa numbers under 15 for softwood. This corresponds to lignin contents of about 1.5 percent and 2.3 percent, respectively. Full-scale mill experience has demonstrated that these low kappa pulps have strengths equal to those of the 25 to 35 kappa pulps produced by conventional cooking methods (Elliott, 1989; Whitley et al. 1990). The Longview Fibre mill pulped to very low kappa with only modest loss in strength (Haas, 1990). The pulp viscosity was low, but under extended cooking conditions, the viscosity is not a valid indicator of pulp strength.

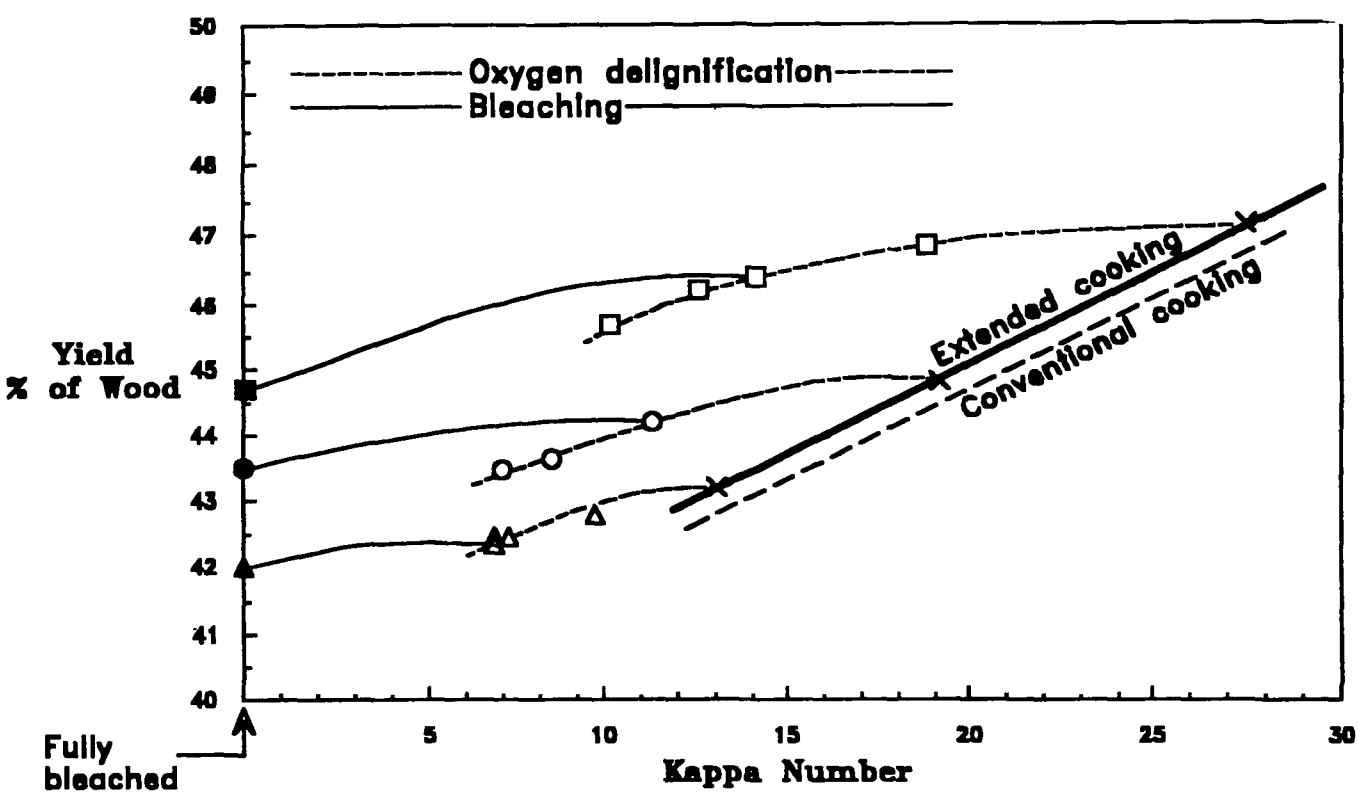
These experiences suggest that extended delignification within the digester has not yet been exploited to its maximum potential, and that further developments can be expected over the next few years. The limiting factor could well be yield loss. If the operating techniques or equipment modifications can be developed so that postbleaching yield is acceptable, or the loss minor, then very low lignin content pulps will be produced in the future by extended cooking technologies.

That some loss in cooking yield occurs when cooking to very low kappa numbers is indicated in Figure 2 (Gullichsen, 1991). For example if a mill were cooking to 38 kappa, the yield would be 47 percent. If the process is modified to operate with a kappa number of 20 leaving the digester, the yield would be 45 percent. If the kappa were lowered to 15, the yield would be 43.5 percent. However, this loss is partially or perhaps completely offset by the substantial reduction in screen rejects from the cooked pulp. The pulp from conventional cooks contains 2 to 3 percent knots and poorly cooked fiber that must be removed from the pulp by the brown stock screening system. In principle, these screen rejects can be recovered by reprocessing, but few mills accomplish this because of practical difficulties in operating the reject recovery process.

■ **Current Installations: Capital and Operating Costs.** Martin MacLeod (1992) presented data indicating that the world capacity for extended cooking of kraft pulps was approximately 11 million tons per year or about 20 percent of world bleached kraft capacity. Seventeen of the 34 installations listed by MacLeod were in the United States. Approximately half the installations listed for continuous digesters were retrofits to existing installations, while the remainder were new digesters. Only one of the seven batch digester installations listed was a retrofit.

The capital cost of retrofitting extended cooking to our example mill would be $46 million. A reduction of $3.5 million in annual operating costs, would result primarily from the reduced demand for bleaching chemicals. This estimate assumes that all available chlorine dioxide is used to raise the substitution in the first chlorination stage.

The capital cost is high because the only proven way of implementing extended cooking in the example mill requires the installation of a new continuous digester. There would also be an additional, intangible benefit resulting from the modernization of the digester department, which cannot be easily quantified.



Source: Gullichsen 1991

Figure 2.—Yield vs. kappa for extended delignification and bleaching softwood kraft.

If the mill had a continuous digester, the cost to convert it to extended cooking would probably be about $12 million less. In the unlikely event that it had a post-1980 continuous digester, it may well be feasible simply to convert the wash zone to an extended cooking zone, at a capital cost of about $4 million.

Regardless of the capital cost, the environmental benefits and changes in operating costs would be similar (see Table 1 for more cost details).

Brown Stock Washing

As indicated in Figure 1, the pulp is washed downstream of the digester to recover the cooking chemicals and organic material extracted from the wood. Any of the material not recovered in the washers will be discharged with the mill effluent. Washer losses are conventionally expressed in terms of the salt cake loss, and a loss of about 900 kg of salt cake per ton of pulp would represent zero washing efficiency. In the past, it was not uncommon for washing systems to lose over 50 kg of salt cake per ton of pulp, but most mills today lose less than 20 kg per ton, and the best are well below 10 kg per ton. The loss of lignin and related organic matter is roughly equal in magnitude to the salt cake loss.

Improvements in brown stock washing reduce discharges of biological oxygen demand, chemical oxygen demand, resin acids, color, and lignin. The focus of this paper, however, is on chlorinated substances. It is generally considered that the washer loss should be under 10 kg of salt cake per ton of pulp if oxygen delignification is to be successfully implemented. Thus, costs for oxygen delignification technology must include the addition of a brown stock washing stage. The technology is straightforward and well known. The capital costs would be approximately $8 million, and the value of recovered chemicals about $1.4 million per year.

Table 1.—Capital and operating costs for selected pollution prevention measures.

PROCESS OPTION	CAPITAL COST ($ MILLION)	ANNUAL SAVINGS ($ MILLION)	SUBSTITUTION PERCENT	AOX (per blo) kg/t	DETECT TCDD/F	REDUCE BOD kg/day	INCREMENTAL POWER ON-SITE MEGAWATT	INCREMENTAL POWER OFF-SITE MEGAWATT
Base case example mill	0.0	0.0	11	5.3	Yes	0	0.0	0.0
Maximum substitution with Eop & existing ClO_2 capacity	2.8	0.5	30	3.4	Perhaps	0	0.0	(2.6)
Extended cooking (if batch digesters exist)	45.6	3.4	21	2.6	Yes	7,500	0.0	(3.4)
Extended cooking (if older continuous digester)	32.6	2.8	21	2.6	Yes	7,500	0.0	(3.4)
Extended cooking (if suitable continuous exists)	4.6	3.7	21	2.6	Yes	7,500	0.0	(3.4)
Oxygen delignification	27.5	3.3	21	2.6	Yes	13,200	2.0	(3.5)
100% substitution without Eop	15.9	(7.1)	100	2.1	No	0	0.0	5.3
50% substitution without Eop	5.0	(1.9)	50	1.9	Marginal	0	0.0	(2.7)
100% substitution with Eop	13.6	(3.2)	100	1.5	No	0	0.0	1.7
Extended cooking with Eop	47.0	3.3	57	1.3	No	7,500	0.2	(5.3)
Oxygen delignification with 100% substitution	34.7	2.0	100	1.1	No	13,200	2.0	(1.6)
Extended cooking with oxygen delignification	71.6	6.0	68	1.0	No	16,400	2.0	(5.9)
Extended cooking with 100% substitution	54.5	0.07	100	1.0	No	7,500	0.0	(0.1)
Extended cooking with OD and 100% substitution	75.2	4.6	100	0.7	No	16,400	2.0	(4.6)
Extended cooking with OD and Eop	73.0	4.4	84	0.6	No	16,400	2.2	(6.3)

Costs are for the example mill discussed herein and should be interpreted in conjunction with the comments in the text. Values in parentheses are negative.
"Savings" in parentheses represent a cost.
OD = oxygen delignification.
Substitution = substitution of chlorine with chlorine dioxide.
Reduce BOD = reduction of BOD to biological treatment.
TCDD detection level = 10 ppq.

Oxygen Delignification

In traditional kraft mills, the unbleached stock passes to the first chlorine-based bleaching stage immediately after washing. However, since the early 1970s, oxygen delignification has been installed in many European mills and in a growing number of mills in the United States and Canada.

Figure 1 shows the fiber line of a bleached kraft mill flowsheet, including an oxygen delignification system inserted between the brown stock screens and the bleach plant. The key pollution prevention aspect of oxygen delignification is that almost half the lignin remaining in the pulp after the brown stock washing is removed in this stage and recycled to the recovery boiler, where it is burned in an environmentally sound manner.

Oxygen delignification reduces the kappa number of the unbleached pulp by 40 to 50 percent, reducing the quantity of organic material to be extracted from the pulp and discharged to the mill effluent from subsequent chlorine-based bleaching stages. The installation of an oxygen stage will allow most bleached kraft mills to reduce BOD discharges by approximately 50 percent and color by 60 percent. Discharges of organochlorines will be reduced by approximately 35 to 50 percent.

When considering the installation of oxygen delignification technology, it is necessary to evaluate its effects on other parts of the mill process. Equipment that will experience higher loading due to the oxygen delignification system is shaded in Figure 1. Notice the increased load on most of the recovery cycle. In addition, the performance of the brown stock washing systems must be considered, since excellent washing (salt cake loss under 10 kg per ton and COD under 10 kg per ton) is a prerequisite for successful operation of oxygen delignification systems.

■ **Current Installations.** The capacity of oxygen delignification systems in the United States is 8.1 million tons per year (Johnson, 1992). This is a greater proportion of total capacity than in Canada (McCubbin et al. 1991). In Sweden, Japan, and Australasia, all mills operate, or are in the process of installing, oxygen delignification systems. The environmental benefits of oxygen delignification are generally similar to those of extended cooking. U.S. mills have implemented this latter technology to a greater extent than those in Canada and other countries.

The capital and operating costs for retrofitting oxygen delignification to the example mill, alone and in conjunction with other pollution prevention process modifications, are presented in Table 1. They are based on a two-stage, medium consistency system with two-stage, postoxygen washing.

Substitution of Chlorine

Chlorine dioxide is used increasingly to substitute for the traditional molecular chlorine in the first (chlorination) stage of the bleach plant. This practice improves effluent characteristics and pulp quality. For most mills it is the simplest, most widely demonstrated, and lowest capital cost approach for reducing organochlorines, including dioxins. It does not, however, reduce BOD, or wood extractives. Relative to the example mill, 100 percent chlorine dioxide substitution alone could reduce organochlorine discharges by approximately 60 percent.

In the past, chlorine dioxide substitution was implemented primarily to improve pulp quality, but since 1 kg of chlorine dioxide can replace approximately 2.6 kg of molecular chlorine, there is a net reduction in the amount of chlorine used, and a reduction in organochlorine discharges. Today the principal driving force behind increased substitution is the reduction of adsorbable organic halogens (AOX), polychlorinated dibenzodioxins (PCDD), and polychlorinated dibenzofurans (PCDF), but the advantages in pulp quality remain.

■ **Equipment, Modifications, and Dioxin Discharge.** Most mills operate their existing chlorine dioxide generation facilities at maximum capacity; therefore, any increase in chlorine dioxide substitution would require an investment of about $25 million in expanded capacity. It may also be necessary to upgrade mixing equipment and controls at the point of adding the chlorine dioxide solution to the pulp.

Extended cooking, reinforced extraction, and oxygen delignification reduce the total demand for bleaching chemicals, which allows some increase in chlorine dioxide substitution without incurring any capital costs for upgrading the chlorine dioxide manufacturing facilities. In all cost estimates used here, it has been assumed that the mill would elect to use all chlorine dioxide generating capacity released by other process changes to increase the degree of substitution in the first bleaching stage. For example, installation of extended cooking in the base case would raise substitution from 10 to 21 percent, while if Eop were also implemented, substitution could be increased to 57 percent.

On the basis of an extensive review of recent operating experience in almost 50 Canadian bleached kraft mills, Luthe et al. (1992) suggest that dioxins and furans in the final mill effluent will be

nonmeasurable if the active chlorine multiple (ACM) is below a threshold value. That value in turn depends on the extent of chlorine dioxide substitution. ACM is calculated as the ratio of total active chlorine applied in the first chlorination stage to the incoming kappa number. They suggest that this limiting ACM can be calculated as 24 / (150 ClO_2 Substitution percent). These conclusions apply only if dioxin precursors (normally in defoamers) have been eliminated, as is now normal practice in Canada and is believed to be the case in the United States.

If we manipulate the above equation to calculate the substitution level, it becomes: Substitution percent = (150 * ACM - 24)/ACM, which was used to prepare the table and graph shown in Figure 3.

Luthe et al. (1992) define mill discharges as "nonmeasurable" if the discharge of 2,3,7,8 TCDD is under 10 ppq and the discharge of 2,3,7,8 TCDF is under 30 ppq. They prefer to avoid using the concept of detection level, since any measurement close to the detection level is liable to be inaccurate. These criteria are not as low as some may wish, but they are considered to be the lowest values that can be determined with reasonable confidence at the time of writing. It is probable that many mill effluents described as having "no detectable" concentrations of 2,3,7,8 TCDD actually contain very much less than 10 ppq and would remain "nondetectable" even if judged by a more stringent criterion that may well become practical as laboratory experience is gathered.

Mills can be expected to achieve lower discharge rates by optimizing the relatively new bleach sequences introduced in the past few years. These sequences will reduce the formation of organochlorines in general, and dioxins in particular.

■ **Current Installations, Capital, and Operating Costs.** There are no recent surveys of the extent of chlorine dioxide substitution practiced in U.S. mills. Examination of the data presented by Luthe et al. (1992) shows that many Canadian mills have adopted high levels of substitution (>70 percent). It is generally agreed by those familiar with the industry that the United States has not adopted this technology so widely. Until very recently, this fact was also true in Scandinavia, but in the past year, many Scandinavian mills have converted to 100 percent substitution to be able to produce "chlorine-free" pulp. Such pulp would be better described as "chlorine-gas-free."

The example mill discussed herein would require an expanded chlorine dioxide manufacturing plant, improved chemical mixing, and modernized process controls to implement high or 100 percent substitution. The capital cost would be approximately $16 million, and operating costs

Substitution %	Limiting ACM
0.	0.16
5.	0.17
10.	0.17
15.	0.18
20.	0.18
25.	0.19
30.	0.20
35.	0.21
40.	0.22
45.	0.23
50.	0.24
55.	0.25
60.	0.27
65.	0.28
70.	0.30
75.	0.32
80.	0.34
85.	0.37
90.	0.40
95.	0.44
100.	0.48

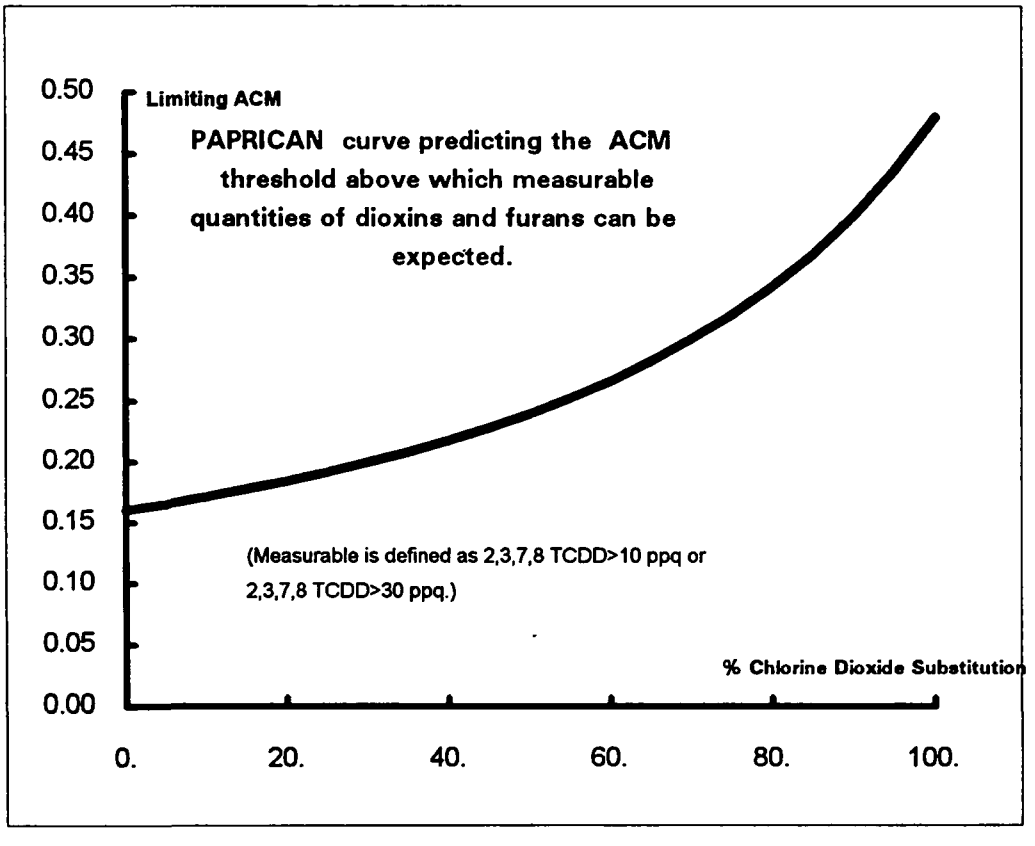


Figure 3.—Chlorine multiple required to eliminate measurable formation of TCDD/F.

would increase by about $7 million per year. If the example mill already had an R3® or SVP® process chlorine dioxide manufacturing system, the latter could be converted to a methanol reduction process, and the necessary bleach plant modifications could be completed for under $5 million, with the aforementioned penalty in operating costs. Virtually all chlorine dioxide manufacturing systems installed since 1970 use the R3® or SVP® processes. Since the life of a chlorine dioxide generator is normally under 20 years, it is reasonable to assume that a large number of the mills in the United States could profit from this opportunity. Many have already done so (see Table 1 for costs-estimates related to raising the chlorine dioxide substitution in various circumstances).

A dozen United States mills have no chlorine dioxide on-site. These mills would have to spend double the capital to upgrade metallurgy in the chlorination stage and to build a greenfield chlorine dioxide plant. Several of these mills use CEH and similar sequences to produce semi-bleached kraft for integrated manufacture of newsprint or similar grades. Instead of undertaking such major capital expenditure, and incurring the associated high operating costs, it appears probable that they will simply replace the kraft mill with a deinking system, to adapt to the current market demands for recycled content in newsprint.

Reinforced Extraction

Since high shear mixers were developed around 1980, it has become increasingly common for mills to reinforce the caustic extraction stages (E, in Fig. 1) with oxygen or hydrogen peroxide. Hastings and Idner (1992) reviewed the current status of this technology, and showed that it is widely used, with some installations using only one of these two oxidants, while some use both. The better systems generally include a small diameter new bleaching tower approximately the same height as the existing E-stage tower.

■ **Oxygen Reinforcement.** Oxygen reinforcement (Eo) alone can be installed at a capital cost somewhat under $1 million in the example mill discussed here. Approximately 5 kg of oxygen are used per ton of pulp, and the principal effect is to reduce the requirement for chlorine dioxide in the later (D) stages by approximately 3 kg per ton of pulp. Initial installations of Eo systems were intended to save costs since 5 kg of oxygen costs only about $0.75, while 3 kg of chlorine dioxide cost approximately $3.60. Since control of organochlorines became a major concern, the principal effect of installing Eo is often considered to be the opportunity to use the 3 kg per ton chlorine dioxide savings to replace approximately 8 kg chlorine per ton pulp in the first (C) bleaching stage. This represents a reduction of up to 15 percent in organochlorine discharge, but eliminates the cost advantage.

■ **Hydrogen Peroxide Reinforcement.** Hydrogen peroxide can be used instead of gaseous oxygen to reinforce the first extraction stage of the bleach plant. The capital cost is normally trivial, since the peroxide vendor generally supplies most of the equipment. However, while the quantity of hydrogen peroxide used is similar to the oxygen that would be used in the Eo process variation, the cost is considerably higher, since the cost of hydrogen peroxide approaches $1.50 per kg. In a practical application, if the objective is optimum reduction of organochlorine formation, the hydrogen peroxide charge would be approximately 4 kg per ton, which would replace 8 kg chlorine per ton of pulp, reducing organochlorine discharges by up to 15 percent.

According to Hastings and Idner (1992), more than 80 percent of the world's bleached kraft mills use some variation of oxygen/hydrogen peroxide reinforced extraction. The author is aware of unpublished data showing that well over 90 percent of Canadian mills do so.

Ozone

Ozone bleaching has been heavily researched, and many pilot plants have been operated over the past 20 years. Five full-scale systems are under construction as of August 1992, with scheduled start-up dates late 1992 and early 1993. This technology offers the possibility of manufacturing totally chlorine-free bleached kraft pulps, but since it is not yet proven on a commercial scale, any cost estimates would be speculative. (Phillips et al. 1992)

Ozone seems likely to be used following extended cooking and oxygen delignification, and promises lower operating costs than current bleaching processes based on 100 percent chlorine dioxide substitution.

LIGNOX™ and Related Processes

The LIGNOX™ process was first applied in the Aspa mill in Sweden in 1991. It used hydrogen peroxide with a chelating agent pretreatment to lower the kappa number of oxygen delignified kraft pulp by about 40 percent (Basta et al. 1991). The LIGNOX™ bleached pulp can be marketed as semibleached kraft, or bleached to full market quality with chlorine dioxide, while discharging

under 0.3 kg adsorbable organic halogens per ton of pulp.

The LIGNOX™ process is patented by EKA Nobel. The principal bleaching chemical used is hydrogen peroxide, which has been used to bleach kraft pulp for many years. The distinguishing features of EKA Nobel's process are the use of chelating agents prior to the addition of hydrogen peroxide, and the operation of the hydrogen peroxide stage at relatively high temperatures with long retention time.

The chlorine-compound-free LIGNOX™ pulp at Aspa had a maximum brightness of about 70 to 75 ISO, and where it can be marketed in this semibleached condition, there is no organochlorine discharge. If the pulp is subsequently bleached with chlorine dioxide to approach 90 ISO, then adsorbable organic halogens discharges can be expected to be well under 0.5 kg per ton of pulp.

More recently, the LIGNOX™ process has been operated at higher temperatures and benefited from further research and improved operating know-how. According to Igerud and Basta (1991), it is possible to bleach Scandinavian softwood pulp to 75 to 78 ISO brightness with strength properties comparable to traditional pulps by operating the chelating stage at high temperature and lowering the unbleached pulp kappa number to 13 or so prior to bleaching. This process requires both extended cooking and oxygen delignification.

Igerud and Basta (1991) conclude that the bleaching sequence O Q EP Z E could produce softwood pulps of about 83 ISO brightness — and with acceptable strength properties. This technology, however, is not practiced on a full scale, and capital cost projections for U.S. mills would be premature.

There are no LIGNOX™ process installations in the United States, but extensive research has been carried out on similar processes based on using a chelating agent and hydrogen peroxide to replace most or all of the chlorine dioxide in bleaching. It seems likely that the most successful applications of this technology will follow the installation of oxygen delignification and extended cooking. There are only a few mills in this category in the United States at present, but several others are in the process of installing the equipment.

LIGNOX™ and related processes can be implemented in existing mills with relatively little capital cost (perhaps for a few million dollars). McCubbin et al. (1991) estimated that the direct operating costs for a bleach plant using the LIGNOX™ process would be Can$70 per ton, whereas a mill using oxygen delignification would manufacture a similar quality pulp for an expenditure of only Can$25 per ton.

Enzyme Assisted Bleaching

A year or so ago, only a few industry researchers knew anything about enzymes, but in the past year many mills have conducted full-scale trials with enzymes as bleaching aids. Researchers are currently looking at many ways to use various types of enzymes to reduce the quantities of chlorine-based chemicals required to bleach pulp; nevertheless, the use of brown stock storage tanks as a reactor seems to dominate mill trials at present.

Enzymes are manufactured from microbiological cultures grown under controlled conditions in closed tanks. After digestion the culture is isolated, the cells are broken down, and the enzyme of interest is isolated. Proteolytic enzymes have been used in washing powder for decades to remove protein spots from cloth. Today, enzymes are being developed for the pulp and paper industry. One example is xylanase, an enzyme that can break the bonds between cellulose and lignin, facilitating delignification prior to bleaching, as a supplement, or perhaps alternative, to oxygen delignification.

Mill trials and commercial operations are based on adding some commercial variation of xylanase and acid to the pulp just upstream of the brown stock high density storage tank. The enzyme has no readily discernible effect on the pulp in storage, but the quantity of chlorine (or other bleaching agent with equivalent oxidizing power) required in the subsequent bleaching stages is reduced about 25 percent. Quantities of the enzyme used are typically under 1 kg per ton of pulp, and several kilograms of sulphuric acid per ton are normally required to lower the pH to the 4 to 6 range required for the enzyme to react as desired. The reaction temperature has to be under about 60 °C.

Some enzyme vendors claim that their product increases tear strength, with no degradation in other properties, while others simply suggest no changes. There appears to be a modest drop in yield (less than 1 percent) but the overall effect on pulp yield is not yet clear.

CFI in Canada and Metsa-Sellu at Aanekoski, Finland, were the only mills mentioned at the non-chlorine bleaching seminar at Hilton Head, South Carolina, in March 1992, as using full-scale enzyme bleaching aids. However, staff from other mills indicated that they had been running trials for several days at a time, and producing significant quantities of pulp; and informal comments at the seminar suggested that several mills are probably using enzymes regularly.

Enzyme manufacturers have indicated that xylanase is as useful after oxygen delignification as it is in mills using traditional bleaching processes. The Aanekoski, Finland, mill has manufactured over 50,000 tons of totally chlorine-free (TCF) pulps using an enzyme, oxygen delignification, and peroxide bleaching. This mill has an MCC® digester, and its operators have indicated privately that the premium for TCF pulp is $100 per ton.

It is probable that enzyme technology will be a routine part of pollution prevention measures in the near future.

Effluent Characteristics

Dioxins

The discharges of polychlorinated dibenzo dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) differ substantially from one technological process to the other. Evaluation of much of the available data on dioxin discharges is complicated by the fact that all the available data were collected from 1988 to 1991. At the beginning of this period, so little was known of the technology for reducing dioxin formation that mills were unable to implement control measures. Since then, intensive research programs in Canada, the United States, and Sweden have made considerable dioxin control knowledge available very rapidly.

Some control measures, such as the control of the quality of defoamer additives (Voss et al. 1988), improved chlorination system control procedures, and the elimination of phencyclidine (PCP) or PCP-treated wood chips, were implemented rapidly, at little cost and without fanfare. There is little doubt that these measures reduce dioxin formation significantly, but there are no surveys available to judge the extent. Most of the pre-1991 data available on dioxin discharges from pulp mills is somewhat outdated.

According to Berry et al. (1991), the formation of dioxins is little affected by the lignin content of the unbleached pulp, but depends primarily on the presence of precursors (contaminated defoamers, chips derived from PCP-treated wood) and the "chlorine multiple." The latter is the ratio of chlorine used for delignification in the first (C or CD) stage of bleaching to the lignin content of the pulp. It is clear that increasing chlorine dioxide substitution is desirable from the standpoint of dioxin control (see Fig. 3).

Berry et al. (1991) conclude, and others agree, that the installation of extended cooking, oxygen delignification, or reinforced extraction have little or no direct effect on dioxin formation. However, in practical cases, where these latter technologies are retrofitted, they reduce the total amount of bleaching agents required in approximate proportion to the drop in unbleached kappa number. Since most mills operate their chlorine dioxide manufacturing facilities at capacity, the reduction in the total bleach chemical demand can be used to raise the chlorine dioxide substitution ratio, as discussed earlier, hence reducing dioxin discharges.

Adsorbable Organic Halogens

The discharge of many chlorinated organic compounds depends closely on the lignin content of the pulp prior to bleaching. McCubbin et al. (1991) presented the graph shown in Figure 4, which summarizes the effects of combinations of extended cooking, oxygen delignification, and high chlorine dioxide substitution on adsorbable organic halogens (AOX) discharges.

AOX discharges from hardwood will normally be substantially lower, since lesser quantities of chlorine based compounds are required to bleach hardwood.

The data in Figure 4 ignore the potential benefit of raising the substitution level by profiting from the lowering of demand for bleaching agents when extended cooking or oxygen delignification, or both, are retrofitted.

Polychlorinated Phenols

The discharge of polychlorinated phenols has been shown by Berry et al. (1991) to be highly dependent on the lignin content (kappa number) of the pulp prior to bleaching. Figure 5 presents a composite of their data and shows the relationship between the unbleached kappa number and the pentachlorophenol toxicity equivalent (TEQ) for softwood pulp in laboratory processing.

The sample mill discussed here manufactures pulp with a kappa number of 30. If extended cooking or oxygen delignification were installed, the kappa number could be 16 to 18, lowering the discharge of polychlorinated phenols by 75 percent. If both these technologies are installed, the kappa number of the unbleached pulp could be as low as 10, and reduce the discharge of polychlorinated phenols by somewhat over 90 percent. High chlorine dioxide substitution also reduces the formation of chlorinated phenols.

Color

Color in bleached kraft mill effluents is not hazardous, and causes little, if any, measurable damage to the receiving water. It is, however, aesthetically undesirable, particularly in rivers with low natural

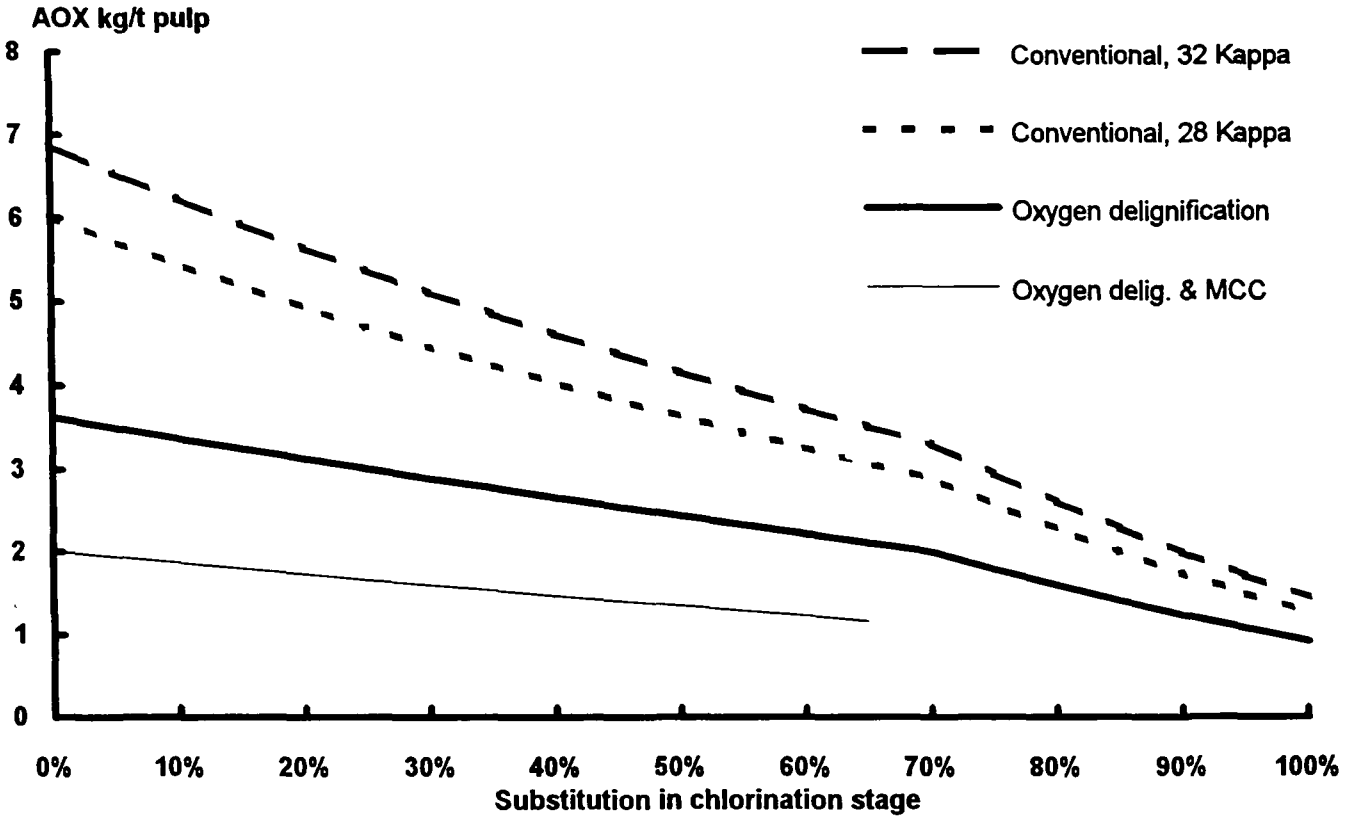


Figure 4.—AOX discharges for various pulping and bleaching conditions (softwood). AOX discharges are prior to biological treatment.

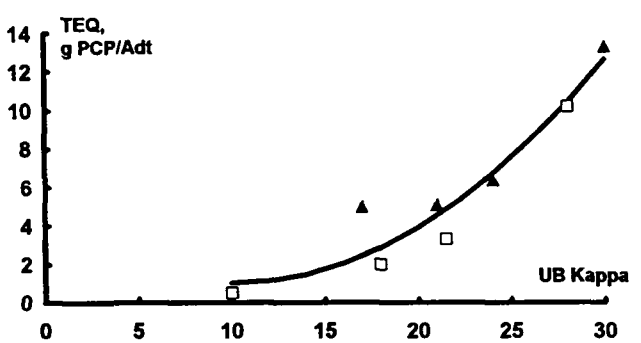


Figure 5.—Formation of pentachlorophenol toxicity equivalents vs. unbleached Kappa number.

color levels. All the previously discussed technologies will reduce color substantially relative to the example mill. Color discharges are roughly proportional to AOX discharges

Zero Effluent

Many secondary fiber mills and at least one market pulp mill (Millar Western's Meadow Lake, Saskatchewan, Canada) operate with no effluent discharge whatsoever. The technology is not yet available to operate a bleached kraft mill without discharging effluent. In principle, the technology exists to operate unbleached kraft mills effluent free, but no such operations have yet been realized.

The most obvious obstacle to eliminating planned process effluents from bleached kraft mills is the use of chlorine-based bleaching agents, which lead to the generation of effluents that must be discharged due to the corrosive nature of the chlorides in a closed cycle process. Mills representing approximately 5 percent of the bleached kraft pulp capacity in the world are capable of producing semibleached, totally chlorine-free, kraft pulp. That is, they do not use any chlorine compounds. Only 10 percent of this TCF capacity is being used, because of weak market demand presumably related to its high cost (about $50 to $100 per ton premium) and somewhat inferior papermaking properties. The brightness for current TCF pulps is about 75 to 80 percent ISO, whereas traditional kraft pulps are bleached to provide 82 to 92 ISO. Current TCF pulps have a tendency to yellow with age, and contain more visible dirt particles than traditional kraft pulps.

With the exception of high chlorine dioxide substitution, all pollution prevention technologies discussed here are logical steps along the path to zero effluent. Chlorine dioxide bleaching equipment would become obsolete in a mill being converted to operate without any process effluent.

The processes that eliminate the use of chlorine compounds in bleaching are based primarily on the use of oxygen in some form, sodium hydroxide, and sulphuric acid. These substances can generally be processed successfully in a conventional kraft recovery cycle. Problems of process control, however, and the removal of trace elements, mostly metals, will have to be resolved before the closed cycle kraft mill becomes practical.

Electrical Energy

Energy consumption is another factor in a mill's pollution prevention cost-to-benefits ratio.

Power Consumption at the Mill and Off-site

Pollution prevention measures, such as oxygen reinforced extraction (pulp mixing); chlorine dioxide substitution (pulp mixing); oxygen delignification (mixing, pumping, and oxygen generation); the addition of a second vessel to continuous digester (pumping); and the replacement of batch digesters with continuous, extended cooking systems (pumping), can have a significant effect on on-site power requirements. Data on changes in power demand at the mill site are presented in Table 2.

The technical options discussed in this presentation change the use of purchased chemicals in the mill. Most chemicals are purchased by the mill from third parties who manufacture them from abundant, naturally occurring raw materials such as sodium chloride, using electric energy.

The effects of these technologies on power demands at the mill and off-site are presented in Table 2, in ascending order of total electrical consumption.

The high substitution of chlorine with chlorine dioxide, clearly, is the most energy demanding technology. The most significant factor in this demand is the energy required to manufacture sodium chlorate (off-site) for the mill's (on-site) chlorine dioxide generators. A significant proportion of sodium chlorate used in the United States is imported from Canada.

Basis for Capital and Operating Costs

The capital cost of retrofitting any of the pollution prevention technologies discussed in this paper depends on the existing installations. There are very wide variations in capital cost for most technologies. Capital costs include equipment, installation, and overheads, such as engineering and project management. They assume that no costs would be incurred for land purchase, which is realistic for most mills, since space requirements are quite small.

The costs of any production losses resulting from downtime for construction have also been neglected. This assumption is realistic for most modifications, since the installation is routinely carried out while the mill is running, and the few hours of mill shut-down time required are coordinated with other scheduled downtime, or sometimes with breakdowns of other equipment. In the case of recovery boiler upgrades, several days or even a few weeks of boiler downtime could be required. Mills have generally maintained production during such periods by shipping black liquor to other mills for processing, or by storing the liquor in temporary ponds for subsequent recovery. Such costs will represent a modest part of the project. They have not been estimated here.

The principal effects of the pollution prevention technologies discussed here will be on chemi-

Table 2.—Effect of pollution prevention on demand for electric energy.

PROCESS OPTIONS	ON-SITE MEGAWATTS	OFF-SITE MEGAWATTS	TOTAL MEGAWATTS
Extended cooking with Eop	0.2	(5.3)	(5.1)
Extended cooking with OD and Eop	2.2	(6.3)	(4.1)
Extended cooking with oxygen delignification	2.0	(5.9)	(3.9)
Extended cooking (if batch digesters exist)	0.0	(3.4)	(3.4)
50% substitution without Eop	0.0	(2.7)	(2.7)
Extended cooking with OD and 100% substitution	2.0	(4.6)	(2.6)
Maximum substitution with Eop and existing ClO_2 capacity	0.0	(2.6)	(2.6)
Oxygen delignification	2.0	(3.5)	(1.5)
Extended cooking with 100% substitution	0.0	(0.1)	(0.1)
Base case example mill	0.0	0.0	0.0
Oxygen delignification with 100% substitution	2.0	(1.6)	0.4
100% substitution with Eop	0.0	1.7	1.7
100% substitution without Eop	0.0	5.3	5.3

Refer to notes on Table 1.

cals and energy consumption. None require increased operating labor, though there may be some labor reductions following the modernization of equipment. Equipment maintenance costs will be increased if new equipment is installed that does not replace older systems.

The effects of a various technologies on the capital and operating costs for the example mill are shown in Table 1.

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Bleaching Cost and Environmental Results at a Modern Kraft Market Pulp Mill

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Parsons & Whittemore
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I plan to share with you the results of bleaching and environmental operations at the Alabama Pine Pulp Company, Claiborne, Alabama, during the plant's first six months of operation. Our results are from a new pulp mill that incorporates all the "bells and whistles" of modern conventional cooking and bleaching technology. The data are from actual operating conditions, limited in timeliness only by the lag time between collection of samples and return of actual results. Very few laboratories are accredited to work on dioxin and adsorbable organic halogens (AOX).

Adapting to Today's Operating Climate

Once upon a time, a start-up report would have focused on the best and fastest way to achieve optimum operating conditions. Those goals contained a lot of self-interest, but they also provided protection of the ecological system by reducing the excessive use of chemicals, power, steam, and water as quickly as possible.

Our industry is now faced with a new "demonology" centered around chlorine. This new "religion" has been accepted as politically and environmentally correct by regulators and the public. There's no need to dwell on it. Because as an industry we were not effective early on in making our case clear and credible, now we must accept the demands imposed on us. Because we produce only market pulp for sale to domestic and overseas customers, if we are going to survive, we have to give our customers what they want. The loud and clear message from a vocal minority is this: "We want high strength, high cleanliness, high brightness, and, by the way, no dioxin and low AOX. Forget about price premiums for your pulp."

The Romans said it best 2,000 years ago: "Dura Lex Sed Lex"; "If you don't like the law, tough luck."

The Alabama Pine Pulp Company (APP) is the newest pulp and paper factory designed, built, and operated by Parsons & Whittemore, Inc., at its southern Alabama site. First on the site, Alabama River Pulp (ARP) began operations at the end of 1978 and now produces approximately 1,200 metric tons per day of hardwood market pulp. Alabama River Newsprint (ARN), a joint venture with Abitibi Price of Toronto, Ontario, Canada, was the second addition. It started in mid-1990 and produces more than 620 metric tons of newsprint per day. Alabama Pine Pulp started in December 1991 and is designed to produce 1,250 metric tons per day of softwood pulp.

The New Mill

APP's fiber line consists of a two-vessel Kamyr hydraulic digester incorporating an extended modified continuous cooking (EMCC®) process and high-heat washing (see Fig. 1). After experimenting with a gamut of kappa number targets (to specify the degree of delignification), we settled on a range of 25 to 27 for maximum strength and full bleachability.

After cooking, the pulp is washed in a Kamyr pressurized diffusion washer, then screened and thickened before entering a two-stage, medium-consistency oxygen delignification system. This

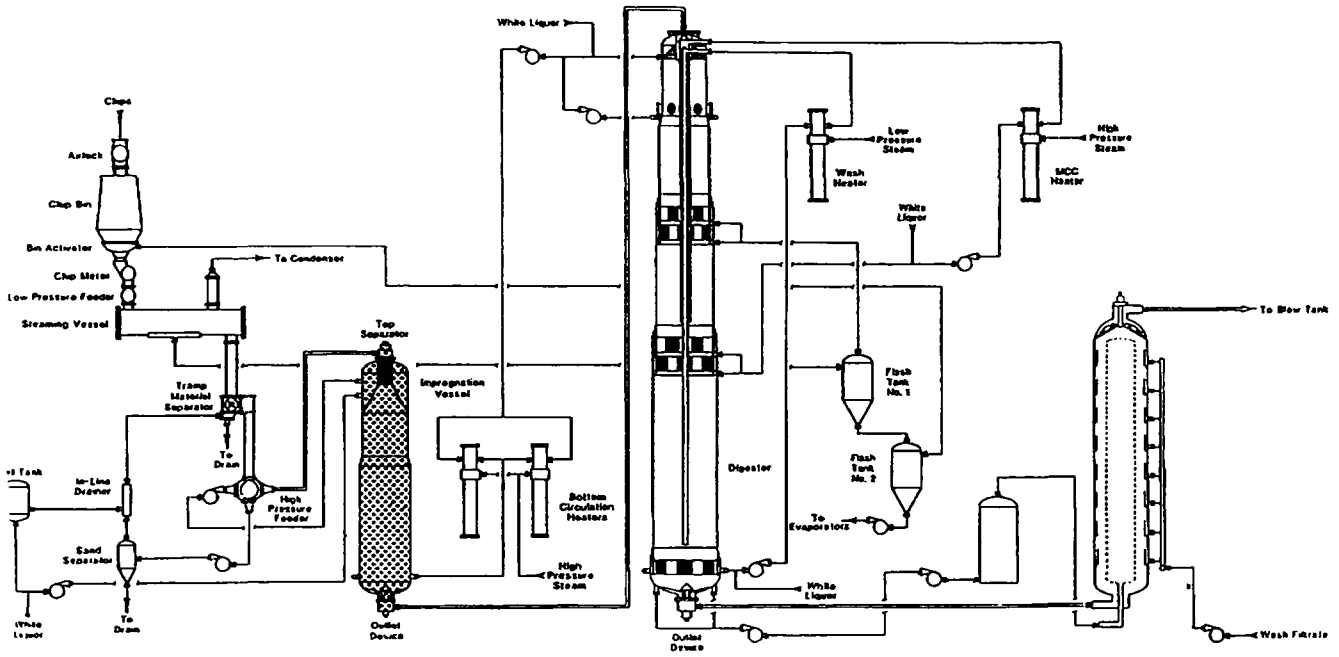


Figure 1.—Two-vessel hydraulic digester with EMCC® and pressure diffuser.

department includes two pressurized oxygen reactors and two pressure diffusion washers. The pulp is delignified to a kappa number of 14 or 15 (see Fig. 2).

Bleaching to a 90-plus ISO brightness is done in a four-stage Kamyr bleach plant. We selected this system because it operates at medium consistency throughout, thus reducing the water and energy requirements (see Fig. 3).

A new chlorine dioxide generating plant (SVP — methanol) was added, with a new electrolytic plant that provides the full requirements of sodium chlorate.

Effluent Treatment and Bleaching Conditions

A third activated sludge module was added for APP, replicating the original 1978 plant. The plant in-

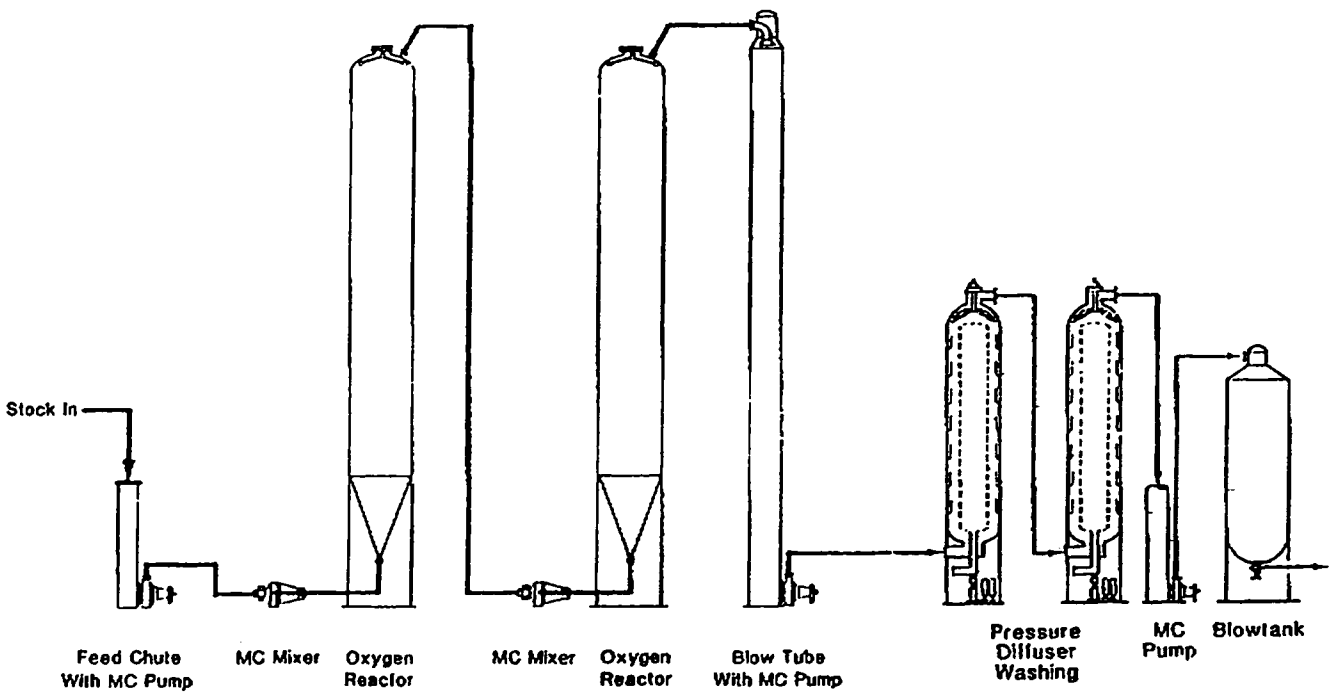


Figure 2.—MC oxygen delignification system.

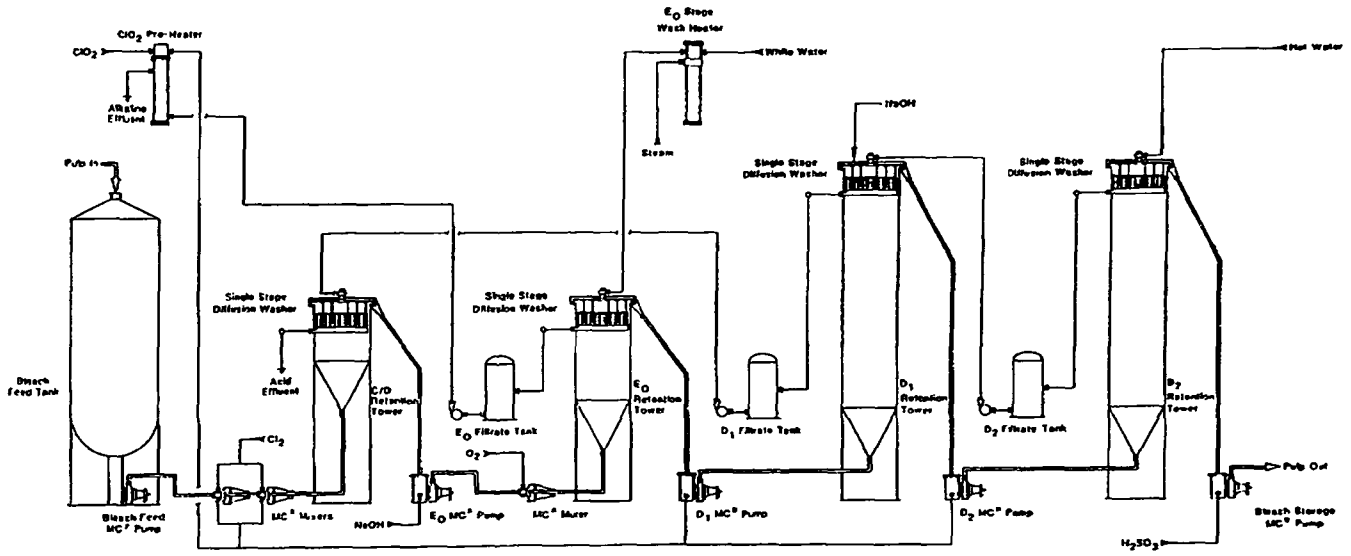


Figure 3.—Diffuser bleach plant C/D - E_{OP} - D - D.

cludes a foam tower, primary clarification, equalization basin, cooling tower, enclosed oxygen reactor, secondary clarifier, thickener, and belt presses for sludge handling. More than 200 metric tons per day of oxygen are produced on site.

We experimented with various degrees of substitution and settled on a 100 percent chlorine dioxide substitution and the elimination of elemental chlorine as the only sure way of achieving nondetectable levels of dioxin. Occasionally we reached this goal at lower substitution levels, but not consistently. The formation of chlorinated dioxins and furans is very dependent on washing efficiency.

Figures 4 to 8 show the effects of various bleaching sequences on dioxin and AOX in pulp, plus AOX in the final effluent. The results are impressive, I think, but they do not come cheap. Figures 9 to 14 show the cost and energy assumptions used in our calculations, and the actual chemical use and cost for the different bleaching sequences.

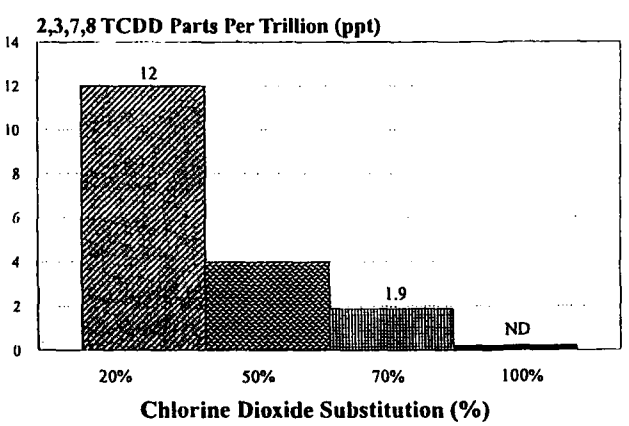


Figure 4.—APP dioxin in pulp.

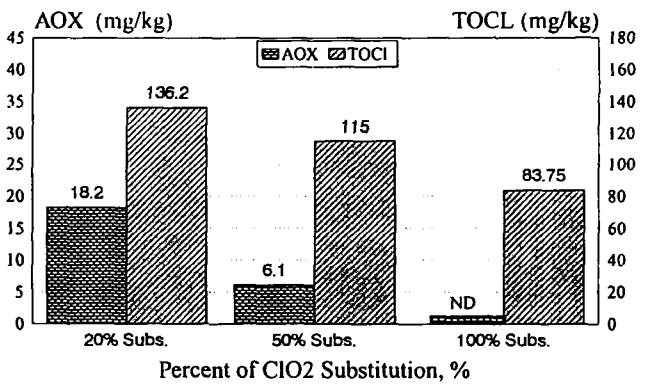
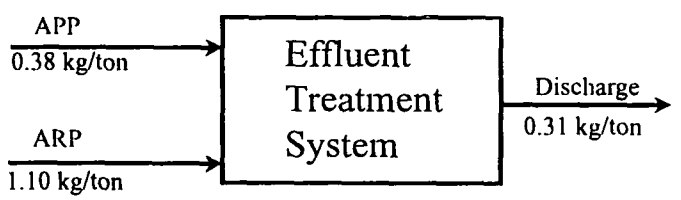
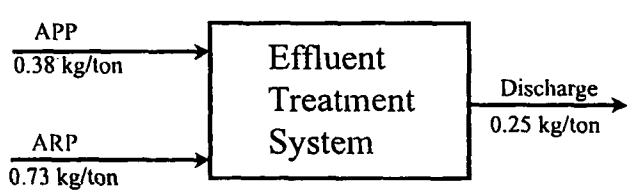


Figure 5.—APP AOX data (AOX and TOCl measured as milligrams per kilogram of dry pulp).



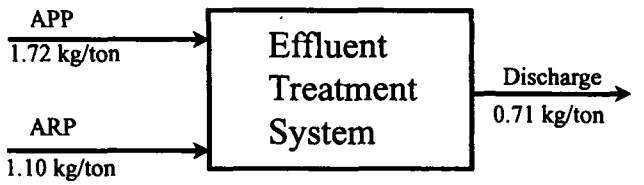
ARP HW Run at 50% ClO2 Substitution,
APP SW Run at 100% ClO2 Substitution.

Figure 6.—AOX reduction for ARP and APP combined effluent treatment systems.



ARP HW Run at 100% ClO2 Substitution,
APP SW Run at 100% ClO2 Substitution.

Figure 7.—AOX reduction for ARP and APP combined effluent treatment system.

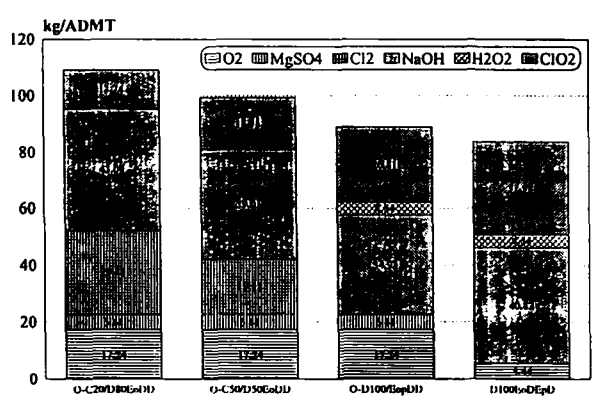


ARP HW Run at 50% ClO2 Substitution,
APP SW Run at 50% ClO2 Substitution.

Figure 8.—AOX reduction for ARP and APP combined effluent treatment system.

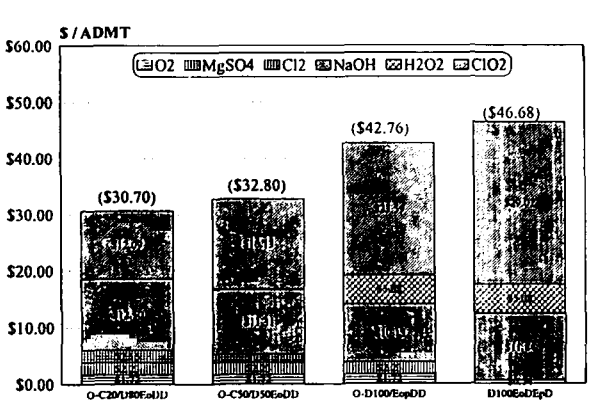
	Cost ($/kg)	Energy (kwh/kg)
• Cl2	0.07	1.70
• ClO2	0.88	9.93
• O2	0.10	0.66
• H2O2	1.12	0.90
• NaOH	0.29	1.50
• Na_Silicate	0.37	
• MgSO4	0.41	
• O3	2.43	22.05

Figure 9.—Chemical cost and energy.



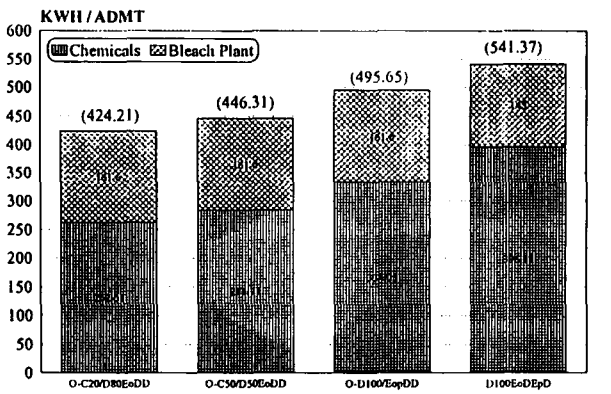
Kappa After O2 Stage: 15 15 15 28 (To Bleach Plant)
(Brightness ISO 90+)

Figure 10.—Chemical usage for different bleaching sequences of softwood pulp.



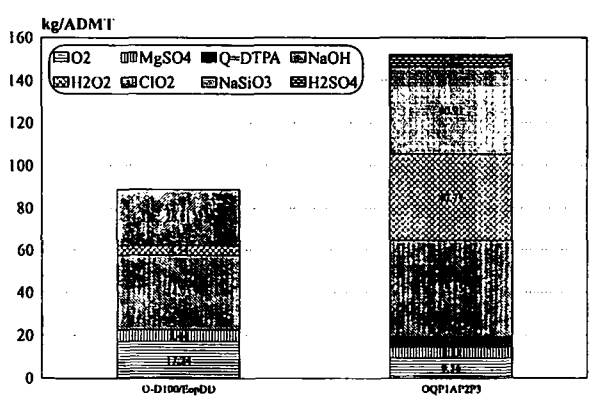
Kappa After O2 Stage: 15 15 15 28 (To Bleach Plant)
Brightness ISO 90+

Figure 11.—Chemical cost for different bleaching sequences of softwood pulp.



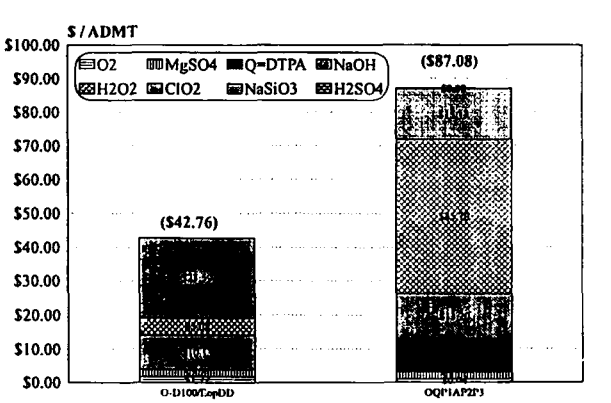
Kappa After O2 Stage: 15 15 15 28 (To Bleach Plant)
Brightness ISO 90+

Figure 12.—Energy requirements for different bleaching sequences of softwood pulp.



Kappa After O2 Stage: 15 10.3
Brightness ISO 90+ 71.9

Figure 13.—Chemical usage for different bleaching sequences of softwood pulp.



Kappa After O2 Stage: 15 10.3
Brightness ISO 90+ 71.9

Figure 14.—Chemical cost for different bleaching sequences of softwood pulp.

Again the final results: the elemental chlorine-free (ECF) pulp costs $10 to $12 per metric ton more to produce than conventional pulp, although the price differential theoretically could be reduced by $5 per metric ton if no peroxide is used. Peroxide gives more stability and consistency to the

final brightness. If a mill does not have an oxygen delignification stage, it can still produce 90-plus brightness ECF pulp — albeit at a higher cost — providing that it starts with a lower than normal Kappa number (after EMCC® for example, or after a soft cook).

As for energy, ECF pulp consumes 70 kilowatt hours per metric ton more than conventional pulp. Just to service our APP and ARP, 170 kilowatt hours of electricity must be produced by oil, coal, water-powered, or nuclear power plants.

Have we tried the production of totally chlorine-free (TCF) pulp? Obviously yes, but only in laboratory trials using our brown stock. The best we could achieve under well-controlled lab conditions was a 70-plus brightness costing $50 per metric ton more than fully bleached pulp. We know, however, that 80-plus brightness has been reported by using an acid stage and the addition of chelates ethylenediaminetetraacetic acid (EDTA).

We have not tested ozone because it requires a more complex apparatus and the cost computation would depend on the process used to produce ozone. The process has good potential, especially for integrated mills that do not need the 90-plus brightness pulp or the fiber strength required in market pulp. On the other hand, it is possible to achieve higher brightness by adding one final dioxide stage to the ozone process. But this sensible solution would give the product little advantage over the modern conventional system used by APP. If the ozonized pulp were touched by the "demon chlorine," it would be deemed unholy and unfit to use.

Conclusion

Our results reflect only six months of operation. We will continue to approach optimal chemical and energy uses, since it takes about two years to bring a large and complex new mill up to full efficiency and productivity standards. But, we have achieved our original goal — nondetectable dioxin in the products and minimal organochlorines in the effluent. Our system shows that a conventional bleaching technology, using the latest pulping and bleaching processes, can protect the environment. Our effluent meets all acute and chronic toxicity tests, which cannot be said of some other chlorine-free bleaching techniques.

So what about chlorine? The oceans contain tons of chlorine and produce millions of tons of organochlorines. In fact, on planet Earth, much more dioxin is formed naturally than by all the pulp mills involved in bleaching practices. With an atomic number of 17, chlorine was obviously formed very early after the Big Bang, perhaps 15 billion years ago, and it will be with us a few billion years more. I think it's safe from extinction — even if we don't rename Greenpeace according to its Greek roots: Chlor-peace. I could work for such peace.

Challenges in the Development of Totally Chlorine-free Kraft Pulp Bleaching Technology

C. Roger Cook
Vice President, Environment
E.B. Eddy Forest Products Limited
Espanola, Ontario, Canada

The E.B. Eddy Kraft Mill in Espanola is working to develop a chlorine-free bleaching technology. Using adsorbable organic halogens (AOX) as a measure of progress toward chlorine-free pulp production, the Espanola mill has reduced its AOX discharge level from 5 kg of AOX per metric ton (tonne) of pulp to a value of 0.6 kg of AOX per tonne using a combination of oxygen delignification, modified continuous cooking (MCC®), chlorine dioxide substitution, and effluent treatment. The company is now evaluating a series of options for the next stage, including the development of ozone bleaching as one of these options.

A pilot study on ozone bleaching is now in progress with an expected completion date of early 1993. The decision to invest in ozone technology will depend on the results of the pilot study and on the market projections for demand of chlorine-free pulp and papers. As with all work to date, the company is looking for equivalent quality, no increase in variability, a satisfactory bleaching cost evaluation, and overall environmental benefits.

The market for a totally chlorine-free (TCF) bleached kraft pulp that will also satisfy customers' demands for quality, value, and environmentally friendly products is going to increase. Measures of quality and value are well established and accepted by producers and customers alike. However, the methods for assessing environmental friendliness are not nearly so clear-cut. At the moment, chlorinated organics (measured as AOX) and the extent of recycled content are the dominant measures, but it is unlikely that they will remain the only measures to assess the environmental impact of pulp production. Governments around the world are eager to prevent the proliferation of unsubstantiated environmental claims on product labels. These so-called Eco Labeling schemes include air emissions quantities and effluent quality, and they are also likely to include energy consumption standards.

At present, the high costs associated with chlorine-free pulp manufacturing are holding down demand. Customers are reluctant to pay the extra premium for TCF pulp. Yet world demand for chlorine-free kraft pulp is expected to be 2 million tonnes per year by 1995, or about 6 percent of the total world demand for kraft pulp — currently, that's about 30 million tonnes per year. This demand for TCF pulp would continue to accelerate if high quality chlorine-free products could be manufactured at bleaching costs close to current, conventional costs.

Technological Know-how

The technological challenge is to make high quality chlorine-free pulp at the right price. Energy use and the notion of recovering some of the bleaching chemicals for reuse are part of the economics of the chlorine-free bleaching process. Alternate bleaching chemicals are more expensive than chlorine on a pound-per-pound basis. Therefore, if the operating cost of chlorine-free bleaching is to be held to reasonable levels, it is apparent that less of the alternate chemical must be used; that is, we must set the kappa number of the pulp as low as possible.

Financial Resources and Risks

Having good market research and a good pilot study on ozone bleaching not only guarantees that full-scale equipment will produce a salable product; it also provides the basis for a good business plan to secure financing for the project. The switch to new technology is most easily accommodated if it is accompanied by plant expansions or construction of a new mill. These factors also have a significant bearing on timing.

The need to survive in a fiercely competitive marketplace drives the willingness to take risks. The companies that are now working on chlorine-free kraft bleaching are also learning how to thrive in an atmosphere of constant change. Generally speaking, they are committed to continuous improvement and are ready to take calculated risks to succeed. If TCF pulp can be produced at equivalent quality and without increasing costs, then the risks involved with the new technology are manageable.

Overview of E.B. Eddy Company

E.B. Eddy has 1.6 million hectares of forest lands in Northern Ontario that are managed under a forest management agreement with the provincial government. The harvested wood is sent to two company-owned sawmills and turned into 1 million board feet per day of high quality kiln-dried lumber. The sawmill residues and purchased logs are shipped to the kraft mill in Espanola where they are converted into 1,000 tonnes per day of bleached hardwood and softwood pulp. Fifty percent of this pulp goes into the company's own paper mills; the remaining 50 percent goes on the open market. The company makes 700 tonnes per day of fine and specialty papers, for example, food packaging, medical grades and lightweight papers, and some coated grades. In addition, we produce fine recycled-content papers under the Eagle trade name in Canada.

The kraft mill was built in 1948. Because of progressive modernization, the mill's environmental performance is comparable to mills built today. In 1983, the company spent Can$200 million to expand production from 700 to 1,000 tonnes per day.

Chlorine, Bleaching Costs, and Quality

A planned reduction in chlorine use has occurred at the Espanola mill over the past 15 years (see Fig. 1). The first significant drop was in 1977 when the company installed North America's first oxygen delignification system in the mill's softwood line. As a result of this success, the company converted the hardwood line to oxygen in 1980. In the 1983 modernization program, a secondary treatment lagoon was installed. Improvements to pulp washing were made in 1988, and increased chlorine dioxide substitution was instituted in 1989 as part of the dioxin control program. The AOX discharge from the mill has decreased from a value of 5 kg per tonne of pulp in 1976 to the present-day value of 0.6 kg per tonne (C.R. Cook, 1990).

The mill has improved its environmental performance while simultaneously reducing bleaching costs and improving quality. The oxygen delignification system reduced total mill chlorine con-

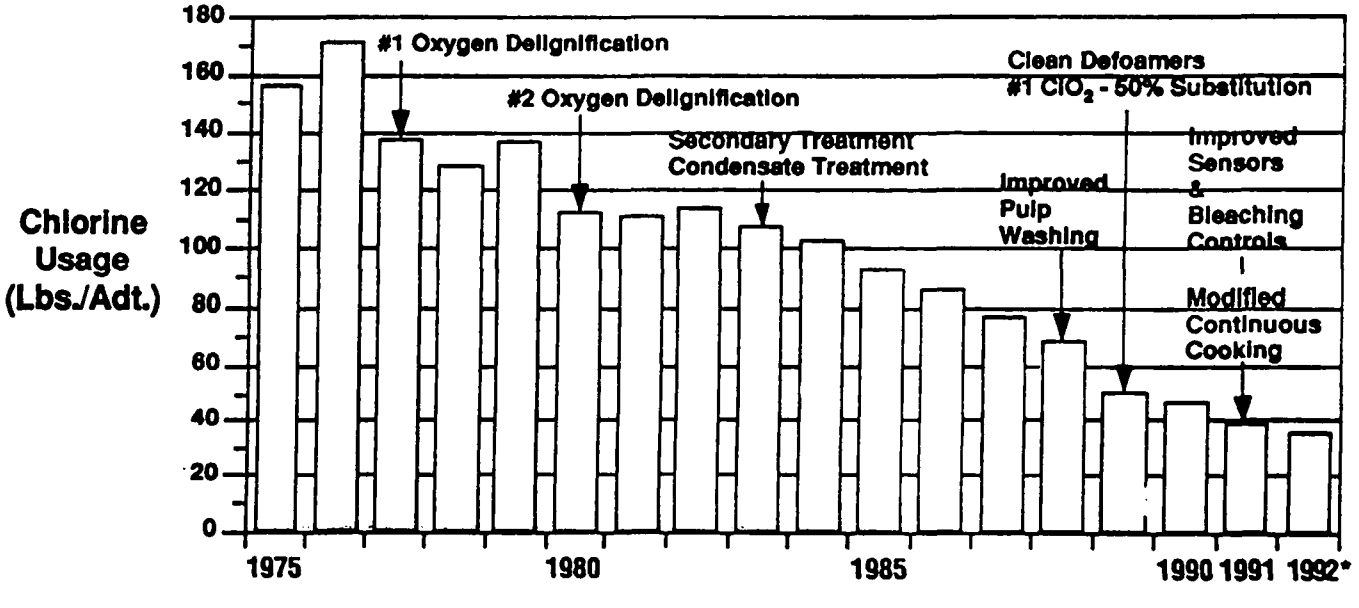


Figure 1.—Significant process changes at the Espanola Mill, 1975 to 1991.

sumption by 30 percent, and softwood bleaching costs by Can$7 per tonne of pulp based on the 1978 evaluation (F.C. Munro et al. 1978). The system paid for itself in about seven years. The savings from oxygen delignification for hardwood were somewhat lower than for softwood. The oxygen system did not change pulp strength, but pulp viscosity decreased slightly. The oxygen system also provided the flexibility to produce various grades of pulp tailor-made to customers' needs.

Extended delignification decreased the bleaching chemical demand by 20 percent (F.C. Munro, 1991). This produced significant savings in the cost of bleaching chemicals. Extended delignification resulted in more uniform pulp quality and cleanliness, yet its strength remained equivalent to conventional pulp.

The use of increased chlorine dioxide substitution also had a positive effect on bleaching costs, mainly because of savings in caustic. The economics for high substitution were optimal when the chlorine dioxide substitution level was 50 percent. The substitution produced equivalent quality pulp in terms of brightness and strength. Thus, the three most significant changes made to the Espanola mill for environmental reasons also produced other benefits.

The Closed Loop Bleach Plant

Replacing chlorine with chlorine dioxide produces significant environmental benefits; however, chlorine dioxide still contains the chlorine atom and still generates sufficient chlorinated organics during the bleaching process to prohibit the recycling of bleach plant effluent back to the kraft recovery cycle. If the mill of the future can completely remove (or substantially reduce) the chlorine from the effluent — or bleach without the use of chlorine or chlorine dioxide — then the caustic used in the bleach plant could be recovered. The mill of the future will likely be a closed cycle operation with a much lower caustic requirement than is necessary today (see Fig. 2). These mills will use other nonchlorinated bleaching agents such as oxygen, ozone, hydrogen peroxide, sodium hydrosulfite, and biologically produced enzymes.

Some mills are interested in developing chlorine-free and chlorine dioxide free technology not only to produce chlorine-free pulp but also to develop a closed loop bleaching plant. It is conceivable that the caustic recovery and the energy recovery from the closed loop concept could generate savings.

Status of the E.B. Eddy Chlorine-free Development Program

The first step in developing chlorine-free technology is to get the kappa number of the pulp to as low a level as possible while maintaining pulp strength. The K number of softwood pulp now entering the bleach plant in Espanola is about eight, which is

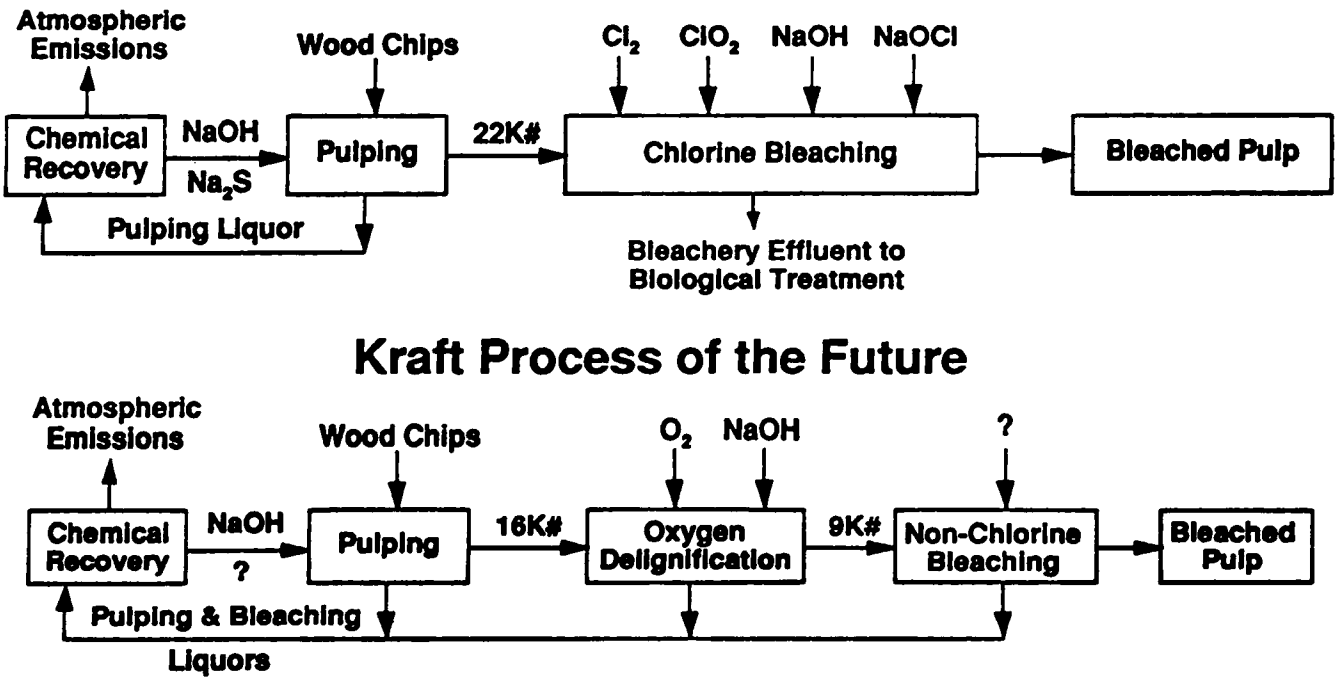


Figure 2.—Comparison of the kraft process.

equivalent to a kappa number of about 11. Ozone pilot studies are being carried out, and a progressive series of pulp bleaching options are now being evaluated. Note that all three options are modifications on the existing sequence OD/CEoHD and all require that the sodium hypochlorite stage be converted to hydrogen peroxide.

- The first option calls for the expansion of the chlorine dioxide generation capacity and the removal of elemental chlorine from the bleaching sequence by using 100 percent chlorine dioxide in the first stage. Then, once the elemental chlorine-free (ECF) grade of pulp is established, convert to ozone bleaching and develop the TCF pulp one bleaching line at a time.
- The second option is to convert to ozone bleaching in the first stage but keep the final D stage in service thereby producing elemental chlorine-free pulp. The final D stage would not be converted to a nonchlorinated compound until after the ozone stage was on stream and proven.
- The third option is to pursue the chlorine-free routes that have already been established using lignox like sequences involving chelating agents, hydrogen peroxide, and enzyme treatments.

The ozone bleaching pilot studies (i.e., the investigation of these options) will continue through 1993 in Espanola in conjunction with Kamyr, Inc., and Canadian Liquid Air. The ozone pilot plant is sized for 5 tonnes per day of low Kappa number, oxygen-delignified brown stock. It is designed to test low, medium, and high consistency for both softwood and hardwood species. The objective is to build on the laboratory work carried out by the mill and by the Pulp and Paper Research Institute of Canada (PAPRICAN), while simultaneously providing engineering data on the possible construction of full-scale ozone bleaching equipment.

Each of these options will be evaluated on the basis of three main criteria: quality, cos's, and their overall environmental benefits, including energy use. If the ozone pilot results satisfy the criteria, then it may not be wise to invest in a new chlorine dioxide generator but simply to proceed with the second option. If the ozone pilot results show that more study is needed, it would be better, perhaps, to pursue the first option and invest in the chlorine dioxide generator to produce elemental chlorine-free pulp (ECF) first. Then, when the ozone studies are complete, the same "phase-in" approach could be followed as when the mill introduced oxygen delignification.

The third option is similar to the lignox sequence that has produced the first commercially available TCF kraft pulps. Some quality and cost questions still have to be answered, however, before Espanola could settle on this option.

Conclusion

The objective of the E.B. Eddy Company is to develop the technological know-how to produce chlorine-free bleached kraft pulp. The decision to install the technology will depend on economics, quality, and environmental benefits. The outcome of the ozone pilot studies is critical to this evaluation.

In the ideal scenario, totally chlorine-free pulp will be produced at the same cost as conventional pulp without sacrificing quality. Experience to date with oxygen delignification, extended delignification, and increased chlorine dioxide substitution has shown that environmental benefits are possible while reducing costs and maintaining pulp quality.

The customers' assessment of environmental friendliness is likely to be guided by the Eco Labeling programs now being developed by various governments around the world. The programs will require producers to attend to more than the adsorbable organic halogens in the mill effluent.

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The Effects of Alternative Pulping and Bleaching Processes on Product Performance — Economic and Environmental Concerns

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Effluents from bleached kraft mills that have been well-treated with primary clarification and aerobic biological treatment have been demonstrated in comprehensive, well-controlled, field tests and commercial practice to create no measurable adverse effects in the aquatic environment (Natl. Counc. Air. Stream Improve. 1983, 1985, 1989). Much of regulatory agencies' current concern arises from studies on untreated mill effluents that show the levels of dissolved wood resins and adsorbable organic halogens (AOX) contained in undiluted, untreated effluents can be environmentally harmful. The regulatory concerns have become political and aesthetic but not health issues. Therefore, proposed regulations should take into account the impact on product quality, economics, and the competitive position of the industry in the global marketplace.

This study presents analysis and conclusions on new and emerging pulping and bleaching technologies, and how they compare either separately or in combination, in their relative impacts on product quality, economics, and reductions in the environmental parameters AOX, color, chlorinated phenols, and Microtox® toxicity. The study is intended to provide a basis for making decisions on how much cost industry — and ultimately the U.S. public — would bear under different requirements for effluent quality standards.

While this paper deals with cost and economics, no one should infer that the U.S. paper industry "pollutes for profit." The U.S. industry has an outstanding record of compliance with some of the most stringent discharge standards in the world. Where it has been shown scientifically that our discharge could potentially harm the environment, the industry has taken prompt action to abate the problem. Environmental spending has exceeded $4 billion since 1988, or approximately 11 percent of the industry's total capital investment.

Methodology

In a presentation at the Nonchlorine Bleaching Conference, held at Hilton Head, SC, in March 1992, L.M. Lancaster, J.J. Renard, and I evaluated the impact of implementing elemental chlorine-free (ECF) and totally chlorine-free (TCF) bleaching processes on kraft pulps cooked either by conventional means or using extended delignification (ED) techniques, with and without oxygen delignification (OD). The alternative processes, and their combinations, were evaluated in terms of capital investment, environmental benefits, and relative operating costs. Using the model mill as a base for the U.S. industry, we extrapolated to total industry cost based on 1990 industry bleached pulp production (see Table 1).

The model mill (see Table 2 for detailed description) used as a basis for the study produces 1,320 air-dried tons per day (ADTPD) of bleached pulp. It is a two-species mill, making 660 tons per day hardwood and 660 tons per day softwood, each on a separate fiber production line. The bleaching sequence to achieve 86 percent brightness for each line was assumed to have been recently modified to reduce the formation of dioxin, using the bleaching sequence: $D_{50}C_DE_O$+pD for softwood and $D_{50}C_DE_O$+pD for hardwood, each with 50 percent substitution of chlorine dioxide for chlorine in the first bleaching stage.

Capital Costs

The equipment needed to convert the model mill to each alternative modified process was identified in terms of

- cooking, washing, screening and cleaning, and bleaching changes;
- equipment needed to evaporate and burn the organic solids from the cooking and the nonchlorine bleaching stages; and
- modifications required to produce the additional cooking liquor necessary for ED and OD, where applicable, and to reburn the additional lime used in the recausticizing process.

National industry averages were used for all costs, including equipment, materials, labor, and indirect costs.

Recovery plant capacity for the model mill was assumed to be a variable factor. Oxygen and extended delignification place a higher demand on the recovery systems because an additional 5 to 10 percent organic and inorganic load is produced from greater delignification prior to bleaching (see Table 3). Three possible situations were analyzed.

1. In the first one, the recovery boiler, evaporators, caustic plant, and lime kiln have sufficient capacity to support the modified systems.

Table 1.—Process options considered to reduce environmental impact of model mill.

PROCESS OPTION	EXTENDED DELIGNIFICATION	OXYGEN DELIGNIFICATION	100% ClO_2 SUBSTITUTION	OZONE BLEACHING	ECF	TCF
$D_{50}\rightarrow C_DE_O$+pD	No	No	No	No	No	No
$D_{100}E_O$+pD	No	No	Yes	No	Yes	No
$OD_{100}E_O$+pD	No	Yes	Yes	No	Yes	No
OZE_O+pD	No	Yes	Yes	Yes	Yes	No
OZE_O+pP	No	Yes	No	Yes	Yes	Yes
[ED]$D_{50}\rightarrow C_DE_O$+pD	Yes	No	No	No	No	No
[ED]$D_{100}E_O$+pD	Yes	No	Yes	No	Yes	No
[ED]$OD_{100}E_O$+pD	Yes	Yes	Yes	No	Yes	No
[ED]OZE_O+pD	Yes	Yes	Yes	Yes	Yes	No
[ED]OZE_O+pP	Yes	Yes	No	Yes	Yes	Yes

Table 2.—Pulp mill process equipment.

EQUIPMENT	DESCRIPTION	CAPACITY
Hardwood digester	One vessel conventional continuous	660 ADTPD
Softwood digester	One vessel conventional continuous	660 ADTPD
Hardwood washing	Two-stage atmospheric diffuser	660 ADTPD
Softwood washing	Two-stage atmospheric diffuser	660 ADTPD
Hardwood screening	Four-stage open	660 ADTPD
Softwood screening	Four-stage open	660 ADTPD
ClO_2 generator	R-8 (converted from R-3)	30 TPD ClO_2
Evaporators	Six-effect	840,000 #/HR
Recovery boiler	Low odor with stationary firing	1,200 B&W TPD
Caustic plant	Conventional design	550,000 #/HR
Lime kiln	(2) conventional rotary kilns	420 TPD CaO
Effluent treatment	Primary clarifier, conventional ASB	8-day lagoon

Table 3.—Recovery system loadings from process modifications.

		WITH ED		WITH OD		WITH ED AND OD	
PROCESS AREA	BASE CASE	VALUE	INCREASE	VALUE	INCREASE	VALUE	INCREASE
Evaporators, #/Hr	703,000	729,000	3.7%	733,000	4.3%	751,000	6.8%
Recovery boiler, #BLS/Hr	161,900	168,000	3.8%	169,000	4.4%	173,100	6.9%
White liquor, #/Hr	464,600	464,600	5.3%	489,200	4.6%	510,000	9.8%
Lime kiln, TPD CaO	352	374	6.4%	368	4.7%	390	10.8%

Table 4.—Capital cost estimate for $OD_{100}E_O$+pD.

	CAPITAL COSTS ($000)		
PROCESS AREA	NO UPGRADE	MINOR UPGRADE	MAJOR UPGRADE
Knotting and screening	$18,400	$18,400	$18,400
Oxygen delignification	37,700	37,700	37,700
Evaporators	0	8,700	24,500
Recovery boiler	0	21,800	78,100
Caustic plant	0	2,200	8,700
Total	$56,100	$88,800	$167,400

2. Sufficient capacity is not there, but the support systems can be upgraded incrementally at modest cost to achieve the requirements of the modified process.
3. The age, the inadequacy of the equipment capacity even with upgrade, or the economic equation dictates that the equipment be replaced with totally new units.

To account for the variable composition of the U.S. industry, for this analysis we assumed that one-third of U.S. mills would be able to install ozone (Z), OD, or ED without additional investment; one-third would require some investment to upgrade the capacity of the existing systems; and one-third would require completely new systems for evaporation, caustic plant and lime kiln, and recovery boiler. Table 4 shows an example calculation of the capital cost to convert the model mill to an $OD_{100}E_O$+pD process. Our three process recovery conditions would cost $56.1 million, $88.8 million, and $167.4 million, respectively.

From the mixed investment requirements for recovery cycle upgrades, we calculated an *average* capital of $104.1 million for the model mill.

Operating Cost

Relevant operating costs for each option were estimated, considering operating labor and materials estimates, maintenance, utilities, and bleaching chemicals, based on industry averages or laboratory extrapolations. Table 5 shows an example calculation of the operating cost increases of the $OD_{100}E_O$+pD process, for each of the three cases of recovery process requirements. Note the chemical and utility costs are the same for each of the cases, but labor and materials vary because they are estimated as a function of the capital cost. From this, assuming the same mixed investment requirements as with the Capital Cost section, we calculated an average annual cost increase of $1.26 million for this particular process modification.

Environmental Impact

Based on our own and published mill studies, as well as laboratory work, including biotreatment simulation, the impact of each option on discharge of color, adsorbable organic halogens, and chlorinated phenolics (expressed as pentachlorophenol equivalents) in biologically treated mill effluent was estimated. Table 6 collects the results of the estimated reduction or increase in each component, when compared with the model mill. Table 6 also summarizes the capital investment and the operating cost changes for both the model mill Base Case and each alternative process considered. The cost of capital on a per-ton basis was calculated by the formula:

Table 5.—Operating cost estimate for $OD_{100}E_O$+pD.

	NET OPERATING COSTS ($000/YEAR)		
NET OPERATING COSTS ($000)	NO UPDRAGE	MINOR UPGRADE	MAJOR UPGRADE
Chemicals	($2,213)	($2,213)	($2,213)
Labor	561	888	1,674
Materials	224	355	670
Utilities	2,019	2,019	2,019
Total	$591	$1,049	$2,150

Table 6.—Cost and environmental impact of process modifications.

PROCESS OPTION	CAPITAL COST ($MM)	OPERATING COST ($/ADT)	TOTAL COST ($/ADT)	% AOX REDUCTION	%CHLOR/PHENOL REDUCTION	% COLOR REDUCTION
D_{50}→C_DE_O+pD	Base	Base	Base	Base	Base	Base
$D_{100}E_O$+pD	$18.8	$9.23	$13.37	67.3	92.6	30.5
$OD_{100}E_O$+pD	$104.1	$2.73	$25.68	81.1	95.7	85.1
OZE_O+pD	$144.3	–$3.73	$28.08	96.1	100.0	99.1
OZE_O+pP	$144.3	$13.72	$45.54	96.1	100.0	99.6
[ED]D_{50}→C_DE_O+pD	$4.9	–$6.19	–$5.11	20.3	19.7	19.9
[ED]$D_{100}E_O$+pD	$23.7	$2.84	$8.07	72.8	94.1	44.4
[ED]$OD_{100}E_O$+pD	$109.0	$0.61	$24.64	85.0	96.6	88.0
[ED]OZE_O+pD	$149.2	–$4.88	$28.01	96.9	100.0	99.1
[ED]OZE_O+pP	$149.2	$12.78	$45.67	100.0	100.0	99.6

$$\text{Cost of Capital} = (I \times r)/[1-(1+r)^{-n}]$$

where:

I = the original capital investment
r = the discount rate (8 percent in all cases), and
n = the number of years in the project life (20 years in all cases)

Additional study was conducted on the Microtox® toxicity of selected process effluents, and will be discussed later.

Product Quality

In all cases, the selected process modifications were capable of achieving comparable bleached pulp brightness and cleanliness. No consideration was given to decreasing product quality. In the case of the processes containing ozone bleaching, a small increment of capital was employed to add a five-stage hydrocyclonic pulp cleaning system and a decker/thickener to remove the additional unbleached particles anticipated for commercial practice, based on our laboratory simulations of this developing process.

With ozone-containing sequences, only commercial application will prove if strength and stiffness comparable to today's high standards can be achieved. Most laboratory evaluation of pulp entail a gross examination of major parameters, such as tensile and tear. As cooking in the digester, and as oxygen bleaching are pushed to lower lignin contents, subtle differences in fiber properties appear, and have been found to result in a loss of bending stiffness that cannot always be recovered by papermaking techniques.

Discussion

Cost/Effectiveness of Alternative Processes

The total cost increase per bleached air-dried ton of production (i.e., cost of capital plus cost of labor, energy, and materials), as a function of the projected levels of adsorbable organic halogens, color, and chlorinated phenols for each alternative process considered, is depicted in Figures 1 to 3. Because each bleaching processes is considered with and without extended delignification, the specific benefit of this particular change is easily recognized in reduced cost and effluent pollutant discharge.

Extended delignification (ED) is a relatively low-cost modification of a continuous digester that permits multiple additions of cooking chemicals, and allows a longer, generally lower temperature cook in which the extent of delignification proceeds past the normal level. In conventional cooking, softwood and hardwood are normally cooked to kappa numbers 30 and 18, respectively, but in extended deliginification, this can be prolonged to kappa numbers of 24 and 14.5 without the normal loss of pulp strength and yield in the conventional cooking process. We estimated the cost of converting the two model mill continuous digesters to ED at $4.9 million, assuming that no modifications to the recovery cycle are required to support the additional alkali or recover the additional organic material.

Similar opportunities do not exist for inexpensively retrofitting batch digesters, which require more extensive equipment modifications and additions to carry out ED. For new digester systems, batch extended delignification is quite competitive with continuous systems.

Application of ED to the base case bleaching process of $D_{50}C_DE_O$+pD resulted in an operating cost reduction of $6.19 per air-dried ton, against the capital investment of $4.9 million, and produces approximately 20 percent reductions in color, AOX, and chlorinated phenols. Of the processes studied, ED is the only modification that appears to have economic merit and the ability to reduce the levels of pollutant discharge.

With the exception of OZE_O+pD, with and without extended delignification, all other process options added operating cost to the model mill. In

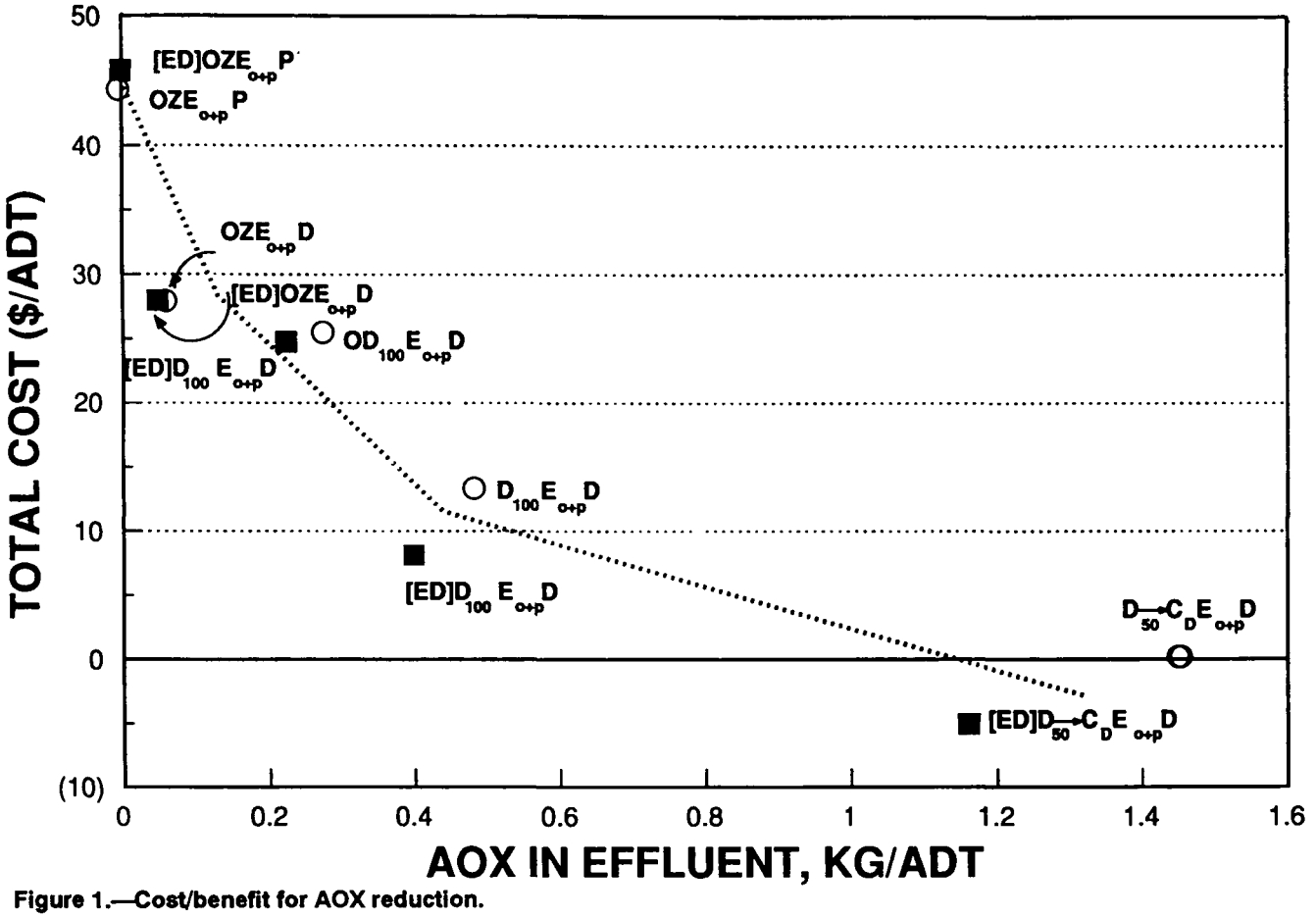

Figure 1.—Cost/benefit for AOX reduction.

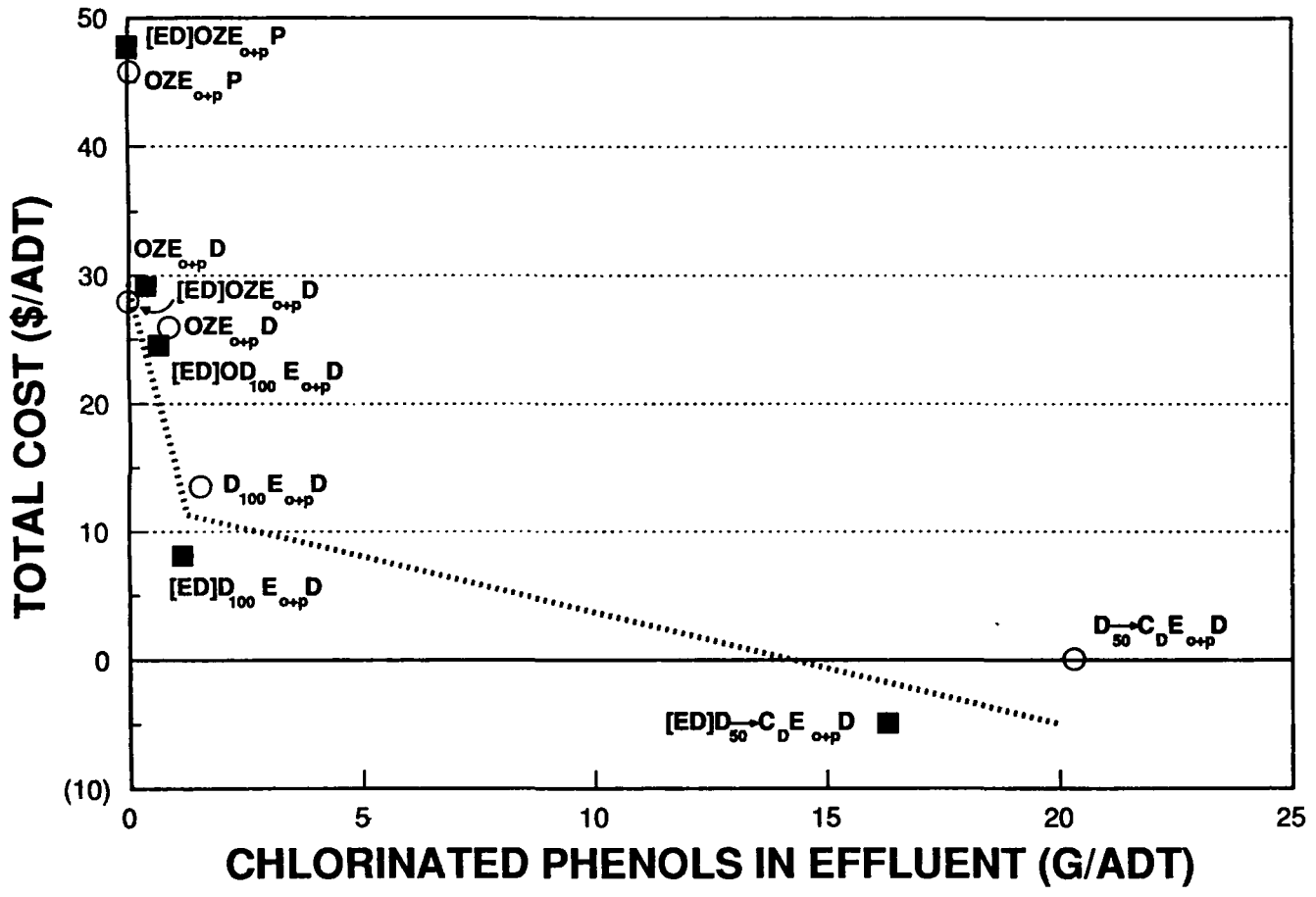

Figure 2.—Cost/benefit for chlorinated phenols reduction.

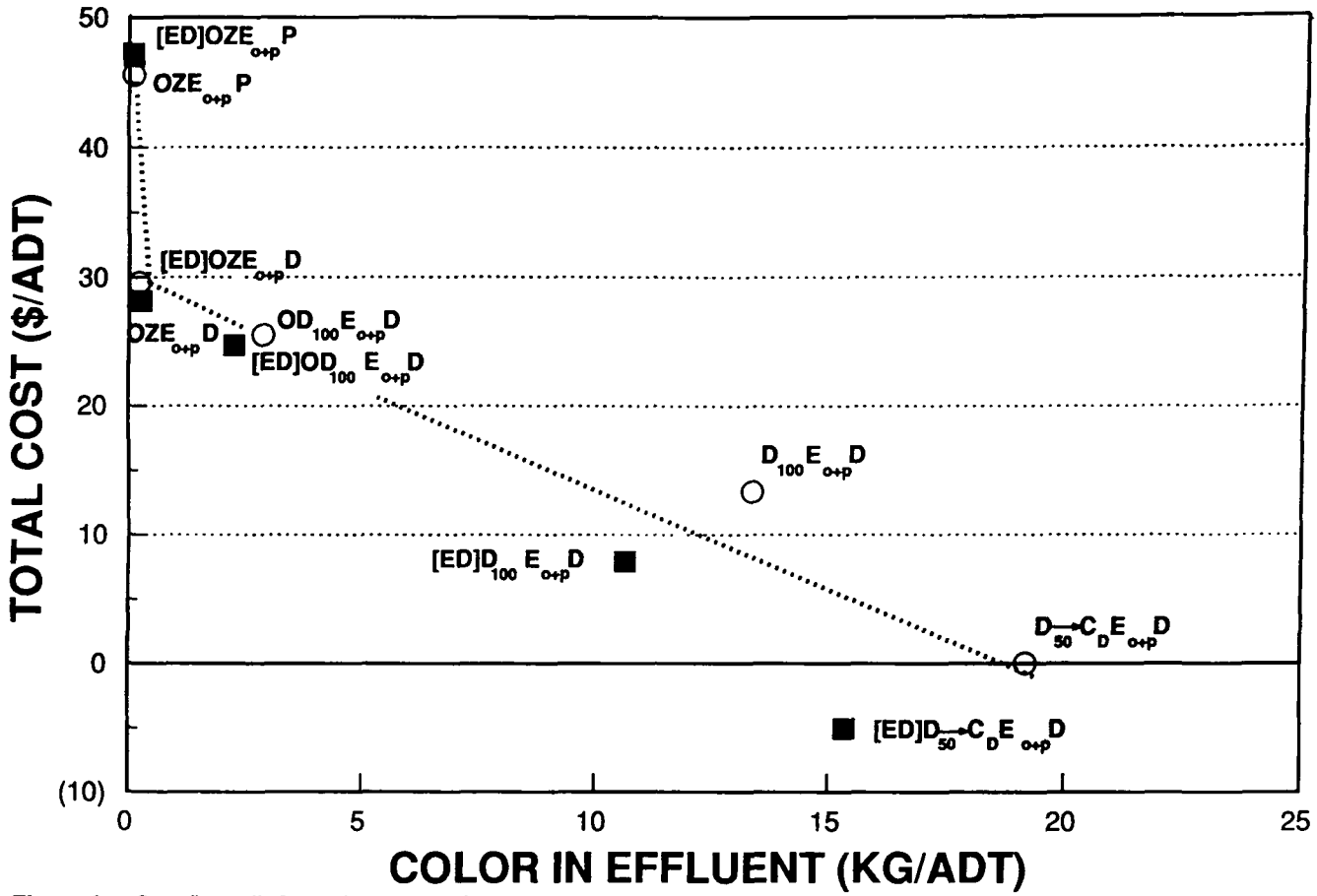

Figure 3.—Cost/benefit for color removal.

the case of OZEo+pD, the average mill capital requirement of $144.3 million leads to a highly unfavorable overall financial investment. In fact, the only process modification examined that was worse from a financial perspective is the TCF sequence OZEo+pP process.

Given that all options are unfavorable financially, it becomes critical to determine which options yield the largest reductions in the pollution parameters under discussion per unit of cost. Each process modification affects specific environmental parameters in a different fashion, and thus each are discussed separately.

AOX Levels Follow Predictable Trend

The levels of adsorbable organic halogens produced by the various processes are a function of the pulp lignin content entering the chlorine-containing bleaching stage, the ratio of elemental chlorine to chlorine dioxide, the ratio of active chlorine chemicals to pulp lignin content (chlorination factor) and the degree of waste treatment. AOX levels follow a predictable trend:

Base Case > 100% Substitution > ED > Oxygen Delignification > Ozone Delignification.

AOX has never been shown to be a measure of any environmental parameter of significance, and its only virtue is that the test is easy to run. AOX ignores the scientific reality that not all organic chlorides are equally toxic, and that they are only toxic when present in amounts sufficient to create toxic effects. An indiscriminate parameter such as AOX is not of value in a discussion of health or environmental impacts. Nevertheless, the U.S. industry has reduced AOX levels by approximately 30 percent in the past four years, largely as a result of modifications made to reduce dioxin levels. Table 7 shows that the direct operating cost plus the cost of capital (Total Cost) for putting into service the TCF process OZEo+pP would be $31.31 for each kilogram of AOX eliminated.

If AOX can be shown to be an important parameter to reduce, a 73 percent reduction could be achieved at much lower cost ($23.7 million versus $144.3 million) by adopting the [ED]D_{100}Eo+pD modification. In fact, the cost of AOX removal to go from [ED]D_{100}Eo+pD to OZEo+pP is $93.68 per incremental kg AOX removed.

The key question from the regulatory point of view is to determine scientifically the adverse impacts, if any, on human health and aquatic life at different levels of AOX discharge within the range produced by these process options. If there are none, then determine what cost penalties regu-

Table 7.—Cost effectiveness of AOX removal.

PROCESS OPTION	CAPITAL COST ($MM)	OPERATING COST ($/ADT)	TOTAL COST ($/ADT)	EFFLUENT AOX (Kg/ADT)	Kg AOX REDUCTION	$/Kg AOX REDUCTION
$D_{50}\rightarrow C_DE_O$+pD	Base	Base	Base	1.45	Base	Base
$D_{100}E_O$+pD	$18.8	$9.23	$13.37	0.48	0.98	$13.65
$OD_{100}E_O$+pD	$104.1	$2.73	$25.68	0.28	1.18	$21.77
OZE_O+pD	$144.3	–$3.73	$28.08	0.06	1.40	$20.09
OZE_O+pP	$144.3	$13.72	$45.54	0.00	1.45	$31.31
[ED]$D_{50}\rightarrow C_DE_O$+pD	$4.9	–$6.19	–$5.11	1.16	0.30	–$17.31
[ED]$D_{100}E_O$+pD	$23.7	$2.84	$8.07	0.40	1.06	$7.62
[ED]$OD_{100}E_O$+pD	$109.0	$0.61	$24.64	0.22	1.24	$19.93
[ED]OZE_O+pD	$149.2	–$4.88	$28.01	0.05	1.41	$19.88
[ED]OZE_O+pP	$149.2	$12.78	$45.67	0.00	1.45	$31.40

lators will require from industry to achieve no measurable benefit.

Chlorinated Phenols

To date, more than 700 naturally produced organic chloride compounds have been characterized (Neidelman and Geigert, 1986), derived by natural reactions of bacteria, fungi, algae, and higher plants and animals. A. Grimvall and his co-workers extensively studied the production of organic chloride compounds by naturally produced chloroperoxidase enzymes, and found significant quantities of 2,4,6-trichlorophenol produced in peat bogs (Grimvall et al. 1989; Asplund et al. 1989, 1990; Hodin et al. 1990). Few chlorinated phenols have been characterized as toxic to humans or marine life, and then only at very high levels.

Working under contract for the Ontario Ministry of the Environment, McKee et al. (1984) derived no effect concentrations (NOEC) for fish (acute and chronic toxicity) and plants for the most common categories of chlorinated phenols found in industrial and municipal wastewaters. In all cases, the NOEC levels were safely above the concentrations typically found in treated mill effluents, even before dilution with a receiving stream takes place (Fig. 4 has been constructed to show the contrast).

When these results are coupled with other, similar characterizations of aquatic impacts and bioconcentration factors of chlorinated phenolics

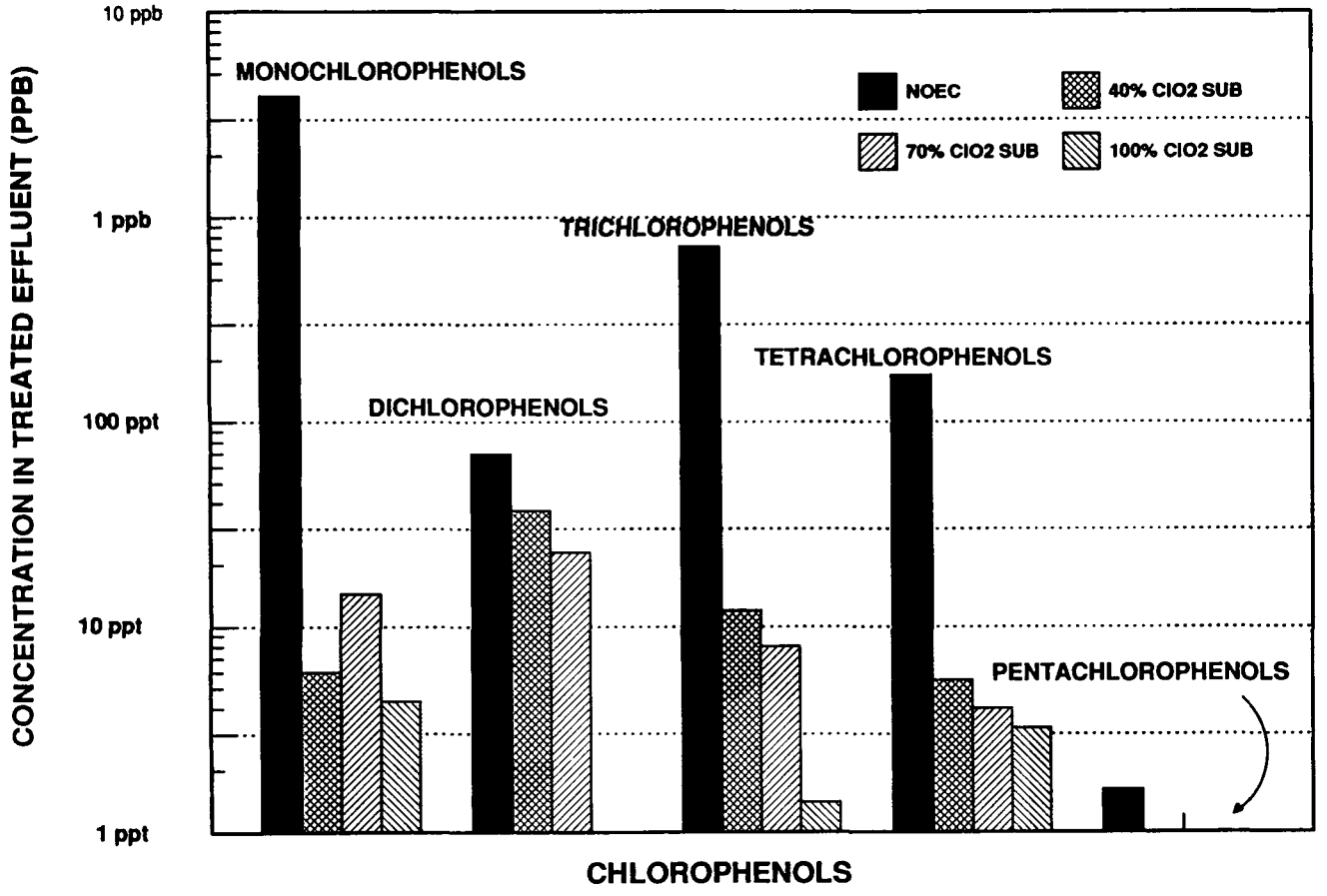

Figure 4.—Comparison of bleached kraft mill effluents with no-effect concentrations.

(McLeay, 1987; Slusaczuk, et al. in press; Yin and Rabmo, 1992), one must conclude that neither the quantities of chlorinated phenols from treated effluents of bleached kraft pulp mills, nor the levels of chlorinated phenols conceivably bioaccumulated in fish or through the food chain, are sufficient to cause environmental concern. The two NCASI stream studies carried out in well-controlled stream conditions, reported elevated chlorinated phenol concentrations in fish tissue, but no effect on the rainbow trout in terms of numbers, mean weight, or survival. No effects were found in terms of lesions, growth, and sexual maturation of individuals exposed as juveniles. Spawning, egg hatching, and larval development were all comparable to control streams. It should be pointed out that these studies were carried out in the early 1980s, before bleaching changes to reduce dioxin were implemented.

As shown in Table 8, in the base case, approximately 20 grams per air-dried ton chlorinated phenols are estimated present in treated effluent, comprising approximately 0.1 percent of the total AOX. Although this level of discharge is well below the no effect concentration, the quantity can be reduced by 93 percent to 1.5 grams per air-dried ton in the model mill by investing in additional ClO_2 capacity at a cost of $18.8 million, and changing the bleaching process to $D_{100}E_O$+pD. The cost of this process change equates to $0.71 per gram chlorinated phenols removed per air-dried ton of pulp over the 20-year project lifetime. To remove the last 1.5 grams per ton in the discharge would require going all the way to TCF processes, resulting in a cost of $27.45 per incremental gram per air-dried ton decrease in chlorinated phenols. Such an expenditure is unwarranted given the absence of adverse effects and environmental significance at current discharge levels.

Color

The color of effluent discharged from bleached kraft mills is largely due to high molecular weight lignins which have been chemically modified by either the pulping process or the bleaching process. This effluent color is totally unrelated to AOX, BOD, effluent toxicity, or chlorinated phenols. In some instances, where little or no dilution of bleach plant effluent is available, color can contribute to reduced aquatic flora by blocking sunlight (Gove, 1980). But no other environmental impact has been documented. The color of rivers with high loadings of bleach plant effluent can show little or no change, depending on the load of colored material in the upstream reaches. The color of river water upstream of mills is frequently due to chemical compounds of humic acid origin, derived from decay of wood and plants and chemically similar to the lignin compounds concentrated in bleach plant effluent. Of all the environmental parameters under discussion, color is an issue distinctly aesthetic in character.

As with the other parameters, production of color is a function of the lignin content of the pulp entering the chlorine-containing bleach stage, and generally follows the same order of process effect as found with AOX.

Table 9 shows that the costs of color reduction are high, requiring $0.95 per kg employing the [ED]$D_{100}E_O$+pD option to achieve nearly 50 percent reduction, or $2.39 per kg using the OZEo+pP process to virtually eliminate color from effluent. By adding ED to the model mill base case bleaching sequence of $D_{50}C_DE_O$+pD, a 20 percent reduction in color can be achieved with a cost savings.

Toxicity

Many of the recent National Pollutant Discharge Elimination System (NPDES) permits have required that treated mill effluents diluted to representative concentrations be tested with *Ceriodaphnia dubia* (water fleas) and *Pimephales promelas* (fathead minnow). Recently, the Microtox® test developed by the Microbics Corporation has found wider use (Johnson et al. 1991; Swedish Environ. Prot. Agency, 1990). The Microtox® test measures the toxicity

Table 8.—Cost effectiveness of chlorinated phenol removal.

PROCESS OPTION	CAPITAL COST ($MM)	OPERATING COST ($/ADT)	TOTAL COST ($/ADT)	EFFLUENT Cl PHENOL (g/ADT)	g/ADT Cl PHENOL REDUCTION	$/g Cl PHENOL REDUCTION
D_{50}→C_DE_O+pD	Base	Base	Base	20.30	Base	Base
$D_{100}E_O$+pD	$18.8	$9.23	$13.37	1.50	18.80	$0.71
$OD_{100}E_O$+pD	$104.1	$2.73	$25.68	0.86	19.43	$1.32
OZE_O+pD	$144.3	–$3.73	$28.08	0.00	20.30	$1.38
OZE_O+pP	$144.3	$13.72	$45.54	0.00	20.30	$2.24
[ED]D_{50}→C_DE_O+pD	$4.9	–$6.19	–$5.11	16.30	4.00	–$1.28
[ED]$D_{100}E_O$+pD	$23.7	$2.84	$8.07	1.20	19.09	$0.42
[ED]$OD_{100}E_O$+pD	$109.0	$0.61	$24.64	0.68	19.61	$1.26
[ED]OZE_O+pD	$149.2	–$4.88	$28.01	0.00	20.30	$1.38
ED]OZE_O+pP	$149.2	$12.78	$45.67	0.00	20.30	$2.25

Table 9.—Cost effectiveness of color removal.

PROCESS OPTION	CAPITAL COST ($MM)	OPERATING COST ($/ADT)	TOTAL COST ($/ADT)	EFFLUENT COLOR (Kg/ADT)	Kg/ADT COLOR REDUCTION	$/Kg COLOR REDUCTION
$D_{50}\rightarrow C_DE_O+pD$	Base	Base	Base	19.16	Base	Base
$D_{100}E_O+pD$	$18.8	$9.23	$13.37	13.31	5.85	$2.29
$OD_{100}E_O+pD$	$104.1	$2.73	$25.68	2.86	16.30	$1.58
OZE_O+pD	$144.3	–$3.73	$28.08	0.16	19.00	$1.48
OZE_O+pP	$144.3	$13.72	$45.54	0.08	19.08	$2.39
$[ED]D_{50}\rightarrow C_DE_O+pD$	$4.9	–$6.19	–$5.11	15.34	3.82	–$1.34
$[ED]D_{100}E_O+pD$	$23.7	$2.84	$8.07	10.65	8.51	$0.95
$[ED]OD_{100}E_O+pD$	$109.0	$0.61	$24.64	2.29	16.87	$1.46
$[ED]OZE_O+pD$	$149.2	–$4.88	$28.01	0.16	19.00	$1.47
$[ED]OZE_O+pP$	$149.2	$12.78	$45.67	0.08	19.08	$2.39

toward the luminescent bacteria *Photobacterium phosporeum*. When these organisms are exposed to and come in contact with a toxicant, the toxicant interferes with their metabolic pathway and attenuates their light transmission in proportion to the toxicity level of the toxicant. Microtox® toxicity is expressed as EC_{50} (extinction coefficient), which indicates the concentration of the toxicant required to reduce 50 percent of the light output. The test is quick, cheap, easy, reproducible and, in some cases, more sensitive to toxicants than the commonly used fish and other organisms.

The process modifications considered for the model mill significantly decrease the original formation of potentially toxic compounds from pulping and bleaching operations, and also have a positive impact on the ability of biotreatment systems to remove effluent toxicity as well as oxygen demanding material and organic chlorides. The enhancement of biotreatability is attributable to the decreased average molecular weight and degree of chlorination, and the increase in the oxidative state of the organic materials in the effluent. Increasing chlorine dioxide substitution preferentially eliminates polychlorinated species in effluents (Fig. 5) and yields organic chloride products that are more amenable to biotreatment than conventional bleaching processes. None of the concentrations of chlorinated phenols, however, approach levels that have been found to have effects in acute and chronic toxicity tests.

The products of totally chlorine free bleached pulps have not been extensively characterized, but a comparison of Microtox® toxicity of effluents

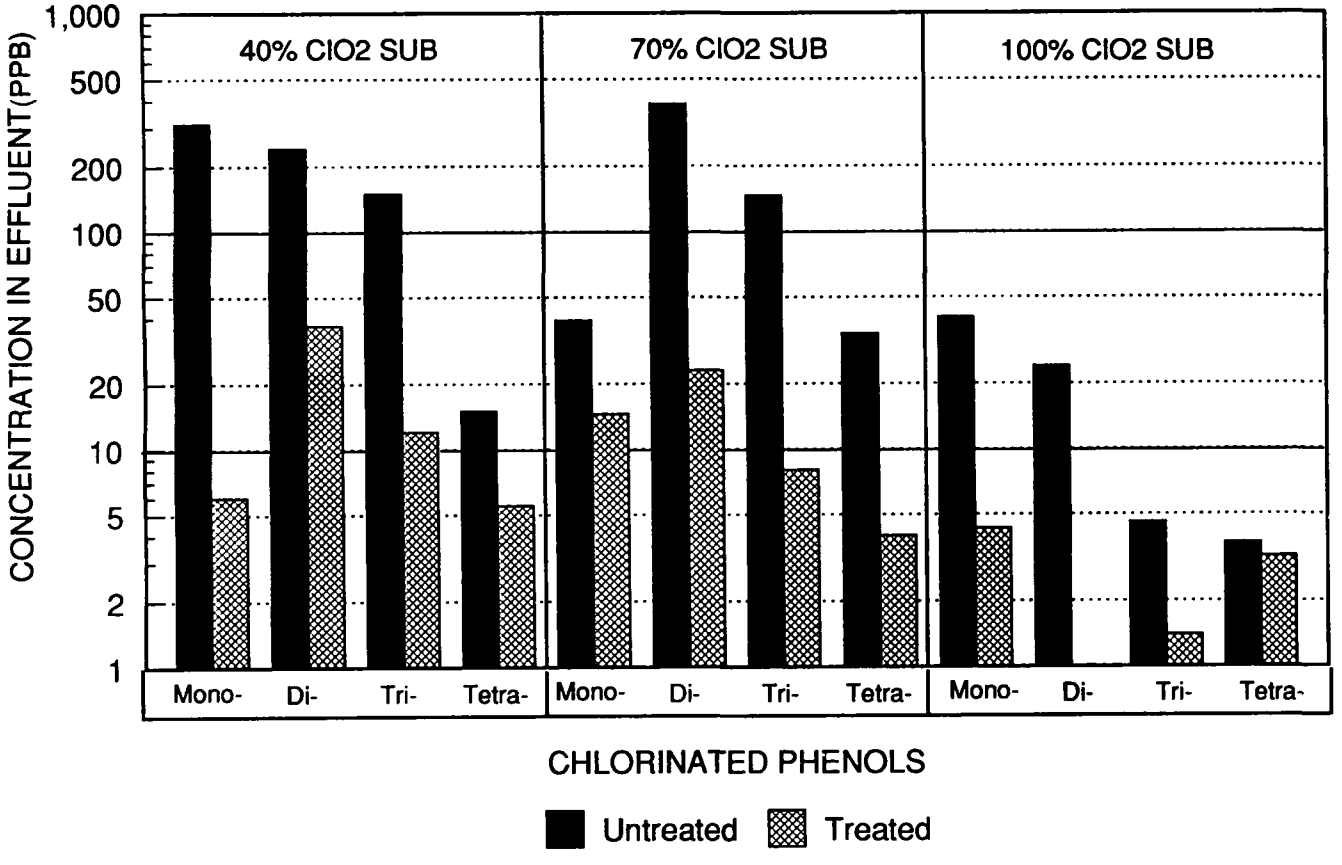

Figure 5.—Effect of chlorine dioxide substitution on biotreatment of chlorinated phenols.

from $D_{100}E_O$+pD and E_OZEZ effluents show that the TCF effluent is more toxic than the 100 percent chlorine dioxide process effluent before simulated biotreatment, and some residual toxicity remained after biotreatment for the TCF process (Fig. 6). We can be confident that toxicity is completely removed by biotreatment in the case of $D_{100}E_O$+pD effluent, but sufficient data do not exist to reach the same conclusion for TCF bleaching effluent, which contains numerous new anthropogenic compounds of an unknown nature.

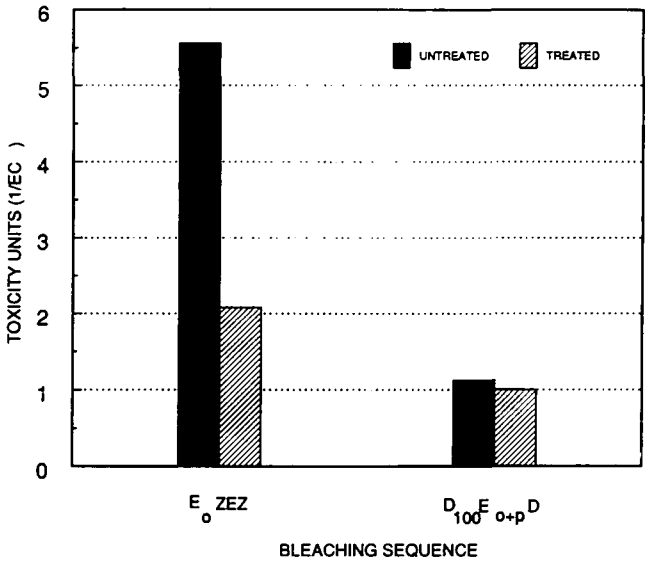

Figure 6.—Toxicity of TCF and chlorine dioxide bleaching effluents.

These results are not particularly surprising, since most toxicity associated with untreated effluents is from resin acids derived from the wood and is associated with the cooking and not the bleaching process. By the Microtox® test, only 10 percent of the toxicity of untreated bleached kraft mill effluent in a modern mill originates with bleaching, while the remainder is due to the pulp mill. Chlorinated phenolics of bleaching origin contribute less than 1 percent of the toxicity of untreated combined bleached kraft mill effluent. One can speculate that chlorine dioxide is a powerful oxidant which neutralizes the toxic effect of the wood resins; the TCF process relies on ozone, which is also a powerful oxidant but apparently not an effective one on resinous materials.

Cost of Implementing Reduced-chlorine Bleaching

To extrapolate the results of the model mill calculations to all U.S. industry, we multiplied the capital requirement for the 1,200 tons per day (TPD) mill by the total U.S. industry annual production divided by the annual production from the model mill. For example, to arrive at the total U.S. industry requirement to implement $OD_{100}E_O$+pD, the average mill requirement for 1,320 ADT/day capacity, shown earlier to be $10.4 million, is multiplied by the ratio of total annual industry tons to total model mill tons:

$$\text{Total Industry Capital} = 104{,}100{,}000 \times \frac{30{,}690{,}000 \text{ AD tons/year}}{\$1{,}320 \text{ AD tons/day} \times 350 \text{ days/year}}$$

$$= \$6{,}915{,}200{,}000$$

Table 10 collects the results of the corresponding calculations for each of the other process changes considered in this study. A range of industry capital costs, from $325.5 million for implementing ED at each of 105 bleach mills, to $9.6 billion to convert all mills to TCF.

The model's accuracy is unknown, although we have found that it predicts well both the capital cost and the operating cost impacts we have estimated individually for each of the 11 International Paper bleached pulp mills. Uncertainty over the status of existing mills that have already implemented one or more of the process modifications could lead to inaccuracies in the industry model, however. Most likely, the number of mills that have progressed past the technology of the base case is equal to the number of mills that are not yet at the base case.

The accuracy of the estimating model is less accurate for any single mill, depending mainly on how closely it resembles the model mill. Since the model mill represents the average U.S. mill, the larger the sample size of facilities being estimated, the more accurate the model will be. As mentioned in the discussion of extended delignification, the technology is more expensive to implement in a batch digester system than a continuous system. In that regard, then, the industry cost of implementing ED must be considered to be understated.

Our analysis assumes that the cost of bleaching chemicals will remain at present levels. Undoubtedly, this assumption understates the cost of supplying caustic soda, a chemical commonly coproduced at 1.1:1 ratio with elemental chlorine in an electrochemical process. Imbalances in demand for caustic without chlorine could create severe shortages of the former, and result in price dislocations. To the extent this occurs, this analysis has understated the industry cost to eliminate elemental chlorine from the bleaching process.

The analysis assumed that the yield of pulp from wood for the modified processes is equal to the yield of pulp from the base case process. Yet, our laboratory studies consistently show a lower yield, especially through the use of ED and OD.

Table 10.—Total U.S. paper industry costs for modified pulping and bleaching processes.

	MODEL MILL			TOTAL INDUSTRY		
PROCESS OPTION	CAPITAL COST ($MM)	OPERATING COST ($/ADT)	TOTAL COST ($/ADT)	CAPITAL COST ($BB)	OPERATING COST ($MM/Y)	NPV @ 8% ($BB)
D_{50}→C_DE_O+pD	Base	Base	Base	Base	Base	Base
$D_{100}E_O$+pD	$18.8	$9.23	$13.37	$1.249	$283.1	($2.544)
$OD_{100}E_O$+pD	$104.1	$2.73	$25.68	$6.915	$83.9	($5.394)
OZE_O+pD	$144.3	–$3.73	$28.08	$9.586	–$114.5	($6.124)
OZE_O+pP	$144.3	$13.72	$45.54	$9.586	$421.2	($9.267)
[ED]D_{50}→C_DE_O+pD	$4.9	–$6.19	–$5.11	$0.325	–$190.1	$883.5
[ED]$D_{100}E_O$+pD	$23.7	$2.84	$8.07	$1.574	$87.3	($1.628)
[ED]$OD_{100}E_O$+pD	$109.0	$0.61	$24.64	$7.241	$18.8	($5.241)
[ED]OZE_O+pD	$149.2	–$4.88	$28.01	$9.911	–$149.8	($6.145)
[ED]OZE_O+pP	$149.2	$12.78	$45.67	$9.911	$392.1	($9.327)

Again, more accurate information on this factor may cause the industrywide cost estimates to be understated. There are no provisions in our analysis to financially write off the investments many mills have recently made to increase use of chlorine dioxide. This would understate the projection made here on the cost of going to TCF.

The cost of electricity assumed for this study is $50 per megawatt hour, a reasonable average cost, but subject to substantial regional variation, and subject to above-average future escalation for the electricity-intensive ozone bleaching process. Our laboratory simulations of TCF bleaching processes show a consistent tendency toward lower pulp strength. Although not factored into this analysis, if this deficit is found in commercial operation, an increase in higher cost softwood pulp use could result. This analysis is a snapshot of the industry's state-of-the-art processes.

One should anticipate improvements in the use of chlorine-containing compounds, just as we have experienced in recent years. At the same time, we can also anticipate advancements in the use of ozone, and, especially, of peroxide. However quick those improvements come, however, they must be accompanied by low cost methods to process the extra load of organic and inorganic solids through the recovery system, or otherwise the capital cost penalties will remain high. One should not overlook the probability that waste treatment technology will improve, as enzymes and bacterial colonies are developed with specific ability to dechlorinate organic matter.

■ **Implications for New Pulp Mills.** A number of the penalties projected here for reducing the use of chlorine and chlorine dioxide would not be applicable to new mill designs to the same extent. Extra capital costs would be incurred for having to construct larger units of process equipment to handle the 5 to 10 percent increases in loadings of evaporators, recovery boilers, caustic plant, and lime kiln. But smaller waste treatment plants could be built in the case where no chlorine-containing compounds were used. Papermill effluent, typically high in biological oxygen demand (BOD) loadings, would still require some form of biological treatment. The [ED]OZEo+pD process shows particular promise for new mill application, because operating costs are actually decreased over the base case process assumed in this study. As industrial experience with high consistency and medium consistency ozone bleaching processes is gained, new pulp mill investments might well be designed after the models that are currently in early stages of development.

■ **Implications for Regulations.** Historically, the U.S. Environmental Protection Agency (EPA) has based its rules on minimizing the impact that industrial processes have on the external environment. The Agency factors in the applicable science to identify true adverse impacts, and considers economics — with the understanding that all industries must balance capital spending to meet their entire spectrum of obligations, which include worker safety, environmental regulations, customer demands for quality improvements, maintenance of existing equipment, and replacement of worn or obsolete units. If some money is left over, it's not a bad idea to spend it to improve productivity and remain globally competitive.

The scientific literature reports no adverse impacts from well-treated, bleached kraft effluents and points to dissolved wood resins, not adsorbable organic halogens, as the greatest contributor to the potential toxicity of untreated effluents. The EPA might well consider tightening the design standards for waste treatment plants and spill collections systems. There is no basis for rules that curtail the use of elemental chlorine or chlorine dioxide, provided that the user can demonstrate through field studies the continued absence of adverse environmental impacts.

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Panel 3:
Technical Perspectives — Performance and Cost

Question and Answer Session

■ **John Clement,** *Babcock & Wilcox:* I have a question for Neil McCubbin. You talked about Miller Western operating with zero effluent, would you comment on what they do with the smelt coming out of the recovery boiler?

■ **Neil McCubbin,** *McCubbin Consultants, Inc.:* They have, I believe, the smallest smelt recovery boiler in the world, certainly the smallest built in recent years. It's built like a kraft boiler, but remember there's no sulphur in the process, so the smelt is molten sodium carbonate, which they solidify and store. One option is to sell it to a kraft mill. I suspect that's a good option, since alkalies are becoming more expensive, and they have it available. They're considering more seriously, however, the idea of putting in a small system to recover the sodium hydroxide using the classic kraft technology. Of course, they have some solid waste to landfill. Zero effluent is zero-piped-to-the-river, but they have the normal sort of solid waste garbage and sludge.

■ **John Clement:** Could you say that right now they've got 100 percent blow down of the sodium chemicals from the black liquor?

■ **Neil McCubbin:** That's correct. If I were Miller Western, I would look very hard at selling that stuff rather than recycling it. They say there's nothing in it that wouldn't recycle, but that's a worry. I'd rather get it out of the way. We'll see what they do. As I said before, they have many smart people on site; they'll find a good answer.

■ **Med Byrd,** *North Carolina State University:* My question is for those of you who have been trying to develop a model for these different options. When you get into the completely closed option, and you're totally chlorine-free, and all effluents can be recycled back to recovery, do your cost estimates include some way of removing the ions, the powerful metals that build up in the system? Is that technology available?

■ **Richard Phillips,** *International Paper:* I can tell you how we handle that. We don't know of any kidney technology that is available to demetalize either effluent or pulp. What we assume is that a chelating stage in the process can serve to remove metals prior to the ozone peroxide. I think this process is necessary to give reasonable efficiency, and it is included in the cost. I didn't say that we were effluent-free in our model. I simply said that we were totally chlorine-compound free.

■ **Roger Cook,** *E.B. Eddy Forest Products Ltd.:* We are running a five tons per day ozone pilot plant at the moment in Espanola. It's a Kamyr pilot plant. We're also working in conjunction with Canadian Liquid Air, so we're focusing on the ozone bleaching side of things. So far our work on how to complete the recycle hasn't been done. In fact, that's why I have no real data on the ozone system. We're going to have to wait until November when our technical people present the results of their work at the TAPPI pulping conference.

■ **Neil McCubbin:** My comments on zero effluent did not include any cost estimates, because I don't think anyone can make accurate estimates right now. The metals are obviously a concern. One thing to notice is that Meadow Lake has been run-

ning since February without any discharge and although it's not a kraft mill they did have roughly the same metals problem — perhaps worse, because they rely on peroxide bleaching. They're using the same wood, and the metals come in the wood. I suspect you'd also find a lot of metals in kraft mills' effluents. This what I meant when I said that getting rid of chlorines is not the whole answer. It's a big chunk. But then the fun will begin.

■ **Med Byrd:** That's part of the problem. If you do not have a chelating stage, where is it? And if you chelate, where does the filter from the chelate go? It has got to go somewhere, either with the pulp you're selling or into some technology to fix it. Given its volume and the dilutions that would be necessary, won't this be a major, hefty cost right there?

■ **Ann Hillyer,** *West Coast Environmental Law:* I have some questions for Neil. You mentioned that if a kraft mill goes to zero effluent, you wouldn't expect a large increase in energy consumption. I've been told by process engineers that Meadow Lake mills increased their energy consumption considerably when they closed the loop. Is the difference that the kraft process is generating its own energy and will continue to do so with the recovered effluent?

■ **Neil McCubbin:** Well, that's one factor. But remember Meadow Lake evaporates and concentrates about 11 cubic meters of effluent per ton, which is is roughly the amount of black liquor in the kraft. Kraft mills are already doing that. Meadow Lake is doing that evaporation in addition to what a normal bleached chemithermomechanical mill would do. Remember, too, when people look at the energy, they probably aren't counting the cost of manufacturing the chlorine off-site.

■ **Ann Hillyer:** My second question was in relation to incinerating or putting the recycled effluent back into the recovery boiler. You mentioned the calls that you've been getting concerning whether or not we're going to be putting things into the air. But if I understood you correctly, you said you thought the recovery boilers would handle that. Are you also putting back into the recovery boilers the sludge from activated treatment systems? And I guess the follow-up to that is, does your average recovery boiler have a high enough temperature and long enough resonance time to be able to do what you're suggesting it can do?

■ **Neil McCubbin:** A recovery boiler is a very high temperature, well-mixed incinerator and as such it can handle the organics from pulping pretty well. EPA did some studies about 8 years ago, asking, in the first round of studies, where the dioxin was coming from. The conclusion that the recovery boilers were not an issue was quickly reached. The activated sludge waste, in other words, waste treatment sludge, is not put into the recovery boiler. It is normally put in the hog fuel boiler. A lot of people have done that. The modern hog fuel boilers, too, are much hotter, better mixed incinerators for treating municipal waste than tended to be common in the past. So I can't get very worried about burning sludge. It's always dangerous to say there's no environmental risk. In 1984, how many people here could spell dioxin? I know I couldn't. But many people have looked for trouble with burning sludge and haven't found any, so I don't worry burning it in the main mill equipment.

■ **Ann Hillyer:** And you're not just talking about fancy-dancy new recovery boilers, you're talking about the average run of the mill boiler that's already installed?

■ **Neil McCubbin:** I'd say most boilers, and certainly most boilers installed since 1970, or modernized since 1970, and that probably covers 75 percent of the capacity. Jack Clement from Babcock & Wilcox will perhaps comment on this question. He knows far more about boilers than I do.

■ **Keith Romig,** *United Paper Workers International Union:* I'd just like to offer a comment. The quality of the discussion here brings us hope that jobs will not be lost in this industry as a consequence of its failing to change fast enough to meet market and regulatory pressures — as in fact happened in so many other industries in the 1980s. Thank you very much.

■ **Rebecca Todd,** *Sierra Club Legal Defense Fund:* I have two questions. First, Mr. Terziotti, I'm curious, in your move to 100 percent substitution, which of your customers, or what segments of the customer population, had requested this move or expressed interest in substitute products?

■ **Luigi Terziotti,** *Parsons & Whittemore:* The request from our customers was not necessarily related to substitution. It was related to dioxin. And they wanted us to help them. They didn't want us to say that we are not integrated or that we just sell pulp. We decided that we'd make that pledge. We'd give them no detectable levels of dioxin. This concern is fairly widespread among customers.

■ **Rebecca Todd:** What specific customers had expressed a concern about dioxin to you?

■ **Luigi Terziotti:** As I said, it was fairly widespread — from European customers making coated papers to people making tissue. It was practically everywhere. We make about 1,000 to 1,200 tons a day of softwood pulp pine and 1,200 tons a day of hardwood pulp, so we cover the whole spectrum of paper manufacturing.

■ **Rebecca Todd:** American, as well as European?

■ **Luigi Terziotti:** It's about 50-50; 50 percent overseas and 50 percent in America.

■ **Rebecca Todd:** I also have a question for Mr. Phillips and Mr. Trice, if he's here. According to your model, Mr. Phillips, the additional cost for TCF pulp was $45 per ton. Is that right? I'm curious how that compares to what Union Camp is experiencing or has predicted that they will experience in their TCF process?

■ **Richard Phillips:** I will defer to Bill Trice, if he's here, since I think he probably has better facts than I do. But, you recall that the numbers he gave yesterday were principally for the process that they plan to implement at Franklin which has a final chlorine dioxide stage. In my charts, you'll notice that the direct variable operating cost, when using a final chlorine dioxide stage, shows a savings over current practice. But when you substitute peroxide for that final chlorine dioxide stage, the costs go negative very quickly because of the bleaching efficiency and the high cost of peroxide. But again, I'll defer to Bill if he's here.

■ **Rebecca Todd:** Thank you.

A Consultant's View of European Government Activities

Jens Folke
Director
European Environmental Research Group
Allerod, Denmark

As an independent consultant, I am not a representative of any European government. I have been involved in regulatory activities as a consultant for the European Community (EC) Commission as well as for the Nordic Council of Ministers, whose members include Denmark, Finland, Iceland, Norway, and Sweden. EC members are Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, and the United Kingdom.

The Nordic countries, particularly Finland and Sweden, are Western Europe's main pulp suppliers (see Fig. 1). The EC countries are dominated by nonintegrated paper and board mills, except for the production of newsprint from mechanical pulp, which involves integrated manufacturing. The main chemical pulp producing countries are France, Portugal, Spain, and Germany (41 of the 44 chemical pulp mills). In France, 60 percent of kraft pulp is made from mixed species of hardwood. Generally, the wood used for pulping in France is of low quality, which means less efficient debarking and a pulp that is more difficult to bleach than most hardwoods.

Germany produces no kraft pulp, only sulfite chemical pulp. Sulfite pulp is easier to bleach but not as strong as kraft, so Germany needs to import large amounts of kraft pulp in the EC (the United Kingdom, France, and Italy are other major importers). Germany, Italy, France, and Spain have 52 of the 64 mechanical pulp mills within the EC. The other seven EC countries are either small pulp producers or produce no pulp at all. Secondary fibers are used extensively in the EC.

European Environmental Protection Cooperation

Cooperation among European countries on the protection of the environment takes place in more than 20 inter-European or international bodies, such as the EC, the Office of Economic Cooperation and Development (OECD), the European Council (established in 1949 and the oldest European cooperative body), the North Atlantic Treaty Organization (NATO), and the United Nations' Economic Commission for Europe (ECE).

Environmental Conventions/Commissions

Environmental cooperation has taken place at 10 conventions, often named for the cities where the final meeting was held. They include the London Commission on Prevention of Marine Pollution from Dumping of Chemical Wastes, the Oslo Commission on Prevention of Marine Pollution from Dumping of Chemical Wastes, the Paris Commission on Prevention of Marine Pollution from Land-based Sources and Rivers, the Helsinki Commission on Prevention of Marine Pollution from Dumping of Chemical Wastes or Land-based Sources and Rivers, and MARPOL (a global convention) on the Prevention on Marine Pollution from Ships.

International Ministers' Conference on the Protection of the North Sea

The first International Ministers' Conference on the Protection of the North Sea was held in Bremen,

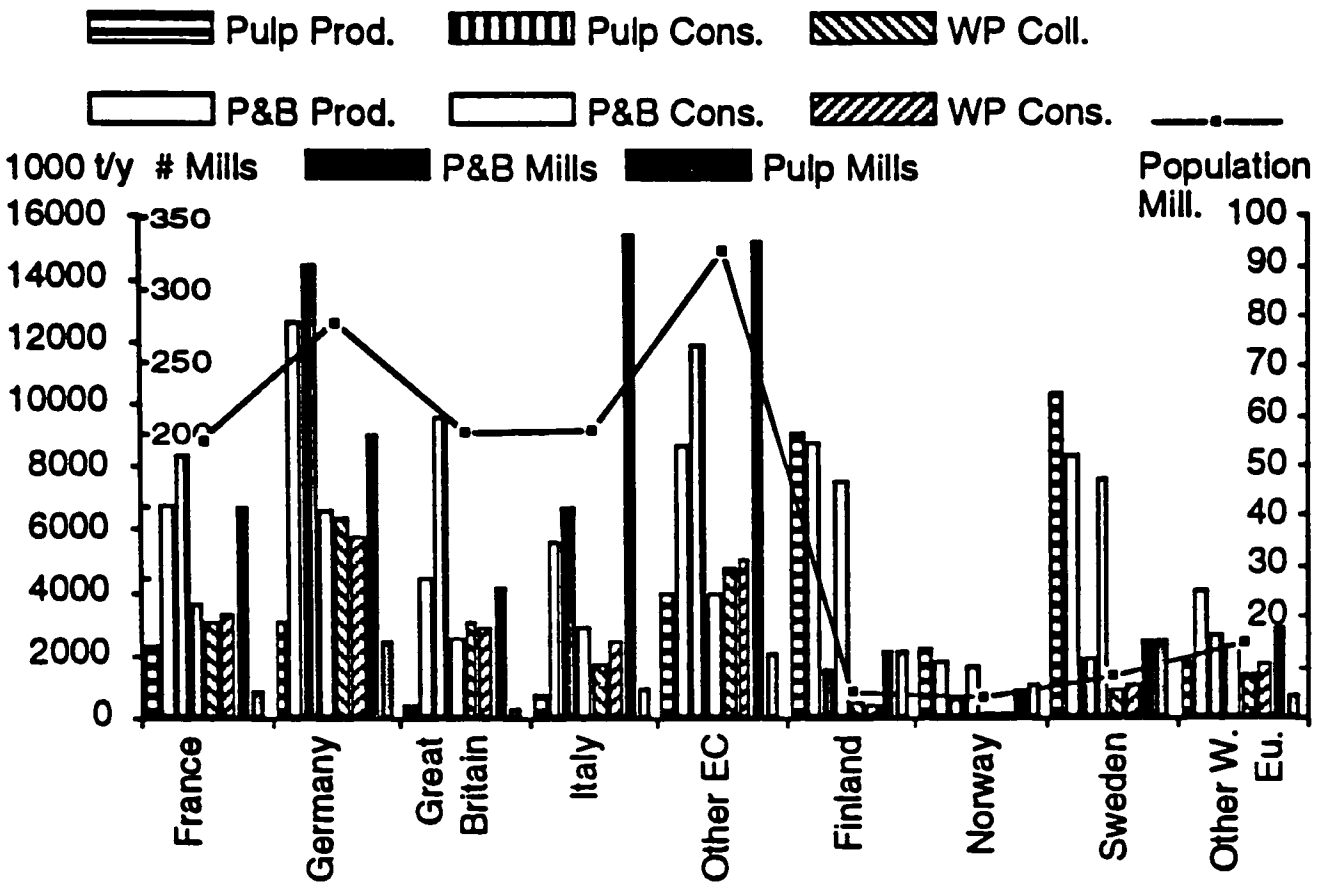


Figure 1.—Western European pulp and paper statistics (1989 Pulp and Paper Industry annual report).

Germany, in 1984. The Bremen Declaration dealt with proposals for the continuous protection of the North Sea. The second conference was held in London on November 24-25, 1987; the third took place in the Netherlands, March 7-8, 1990; and the fourth is to take place in Denmark in 1994-95.

The first two North Sea ministers' conferences produced documents that have only proposition status but have nonetheless been influential. The ministers' declaration from the second conference dealt with the following 10 issues:

1. discharge of hazardous compounds through rivers;
2. discharge of nutritive salts;
3. pollution of the sea through air;
4. dumping and incineration;
5. pollution from ships;
6. pollution from offshore activities;
7. radioactivity;
8. protection of a particularly vulnerable ecosystem;
9. air surveillance; and
10. scientific investigations.

For the first two issues, the goal was to reduce discharges by 50 percent over the next 10 years. The ministers recommended an exchange of information on emission standards and environmental quality standards, based on a limited list of substances or group of substances (which may include nutrients) or processes. They also supported common standards based on the newest scientific evidence and experience and recommended enforcement of these standards.

In the appendix to the London Declaration, examples of potentially significant polluting compounds included persistent halogenated compounds from the organic chemical industry, the pesticide manufacturers, and the pulp and paper industry. Chemical compounds, such as polychlorinated aliphatic hydrocarbons and dioxins, were specifically mentioned.

The ministers' declaration on pulp mills from the Third North Sea Conference noted that by 1995, the discharge of chlorinated substances should not, as an average, exceed 2 kilograms of adsorbable organic halogens (AOX) per ton of air-dried pulp for bleached softwood kraft; 1 kg AOX per ton for bleached hardwood kraft; and 1 kg AOX per ton for bleached sulfite pulp (or any other equivalent limit if more suitable parameters are identified).

Paris Commission

Members of the Paris Commission (PARCOM) are Belgium, Denmark, France, Germany, Ireland, the Netherlands, Norway, Portugal, Spain, and Sweden. The Paris Commission has been directed to

- examine as soon as possible whether more suitable parameters than AOX can be identified;
- develop regulations by 1995 (at the latest) for best available technology to be used for the production of bleached kraft pulp; and, in doing so,
- aim at a maximum content not exceeding 1 kg of AOX per ton of air-dried pulp for all types of bleached kraft pulp, or an equivalent value, if more suitable parameters have been identified.

The Paris Commission meets several times a year. The last meeting, held in Oslo on June 22-26, 1992, produced a draft proposal noting that as of 1993, a new mill should not exceed as a yearly average, the following amounts of discharges:

- bleached pulp mill effluents: 1 kg of adsorbable organic halogens (AOX) per air-dried ton (ADt);
- chlorine multiple: <0.05.
- nonintegrated mill effluents (capacity >50,000 tons): 5 kg of chemical oxygen demand (COD) per ton of paper and 1 kg of total suspended solids (TSS) per ton of paper;
- secondary fiber mill effluents (capacity >25,000 tons): 2 kg of TSS per ton of paper; and
- newsprint mill effluents (capacity >25,000 tons): 2 kg of TSS per ton of paper.

Mills existing before 1993 must adhere to the last two amounts by 1995, to the first two amounts by 1996, and to the third amount by 1997.

France, Portugal, Germany, Spain, the United Kingdom, and Norway had exceptions to the proposal. The group agreed to analyze the problem and to submit their comments to Sweden to draft a new proposal (or proposals) before December 15, 1992.

Helsinki Commission

The Helsinki Commission (HELCOM) also meets several times a year. HELCOM member nations include Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Norway, Poland, Russia, and Sweden. The last meeting was in St. Petersburg, Russia, on May 18-22, 1992. The commission approved a proposal that will immediately limit the annual discharge amounts allowed for each new mill to 65 kg COD per ADt, with biological oxygen demand (BOD) reduced in proportion to COD; and to 60 g of phosphorus per ADt. All mills in existence in 1995 will have to limit their annual discharge amounts to 2 kg of AOX per ADt for softwood bleached kraft mill effluent (BKME), and to 1 kg of AOX per air-dried ton for hardwood BKME — or, as a total average for each country, 1.4 kg of AOX per ADt. Pre-1990 mills have until 2000 to comply with the HELCOM-approved amounts of COD/BOD and phosphorus in their effluents. All HELCOM members must comply with the proposal.

One mill in Denmark uses salt water as its process water, which makes chemical recovery almost impossible. Among the former Soviet bloc countries, even chemical analysis may be unreliable; therefore, collaboration and knowledge transfer from the Nordic countries and Germany to the Eastern European countries are part of the agreement. No standards have been agreed on yet for the wood-containing paper in integrated and nonintegrated mills or for chemithermomechanical pulp (CMTP) mills. As a first step it is agreed that

- water management should aim at high recirculation rates;
- cooling water used for this single purpose should be protected against contamination;
- hazardous chemicals should be replaced by less hazardous ones;
- wastewater from wood-containing paper in integrated and nonintegrated mills should be treated biologically or chemically; and
- wastewater from CTMP operations should be treated anaerobically/aerobically or by aerobic/chemical treatment.

EC Council Directive

In 1975, the EC Commission worked out a proposal for a Council Directive on the reduction of water pollution caused by wood pulp mills in the member states. The Council never finalized this directive proposal, which was based on a French decree from 1972 regulating total suspended solids (TSS) and biological oxygen demand (BOD_5). Since 1972, many EC countries have developed their own effluent standards (see Table 1).

Traditionally, the focus on wastewater discharges from the pulp and paper industry has been on BOD and TSS. Occasionally, regulations have included COD. Belgium operates with four cate-

Table 1.—Current EC emission standards for pulp mills.

PARAMETER	UNIT	BELGIUM (1986)	FRANCE (1972)	GERMANY (1989)	PORTUGAL (1988)	SPAIN (PROPOSAL)
Water	$m3/t_{90}$	120				
TSS	mg/L	120				
	kg/t_{90}		2.5–85		2.5–12.5	4.0–38
COD	mg/L	525		300		
	kg/t_{90}	(63)		5–70		
BOD_5	mg/L	45		(20–50)		
	kg/t_{90}	(5.4)	5.0–80	5	5–45	2.4–24.5
AOX	kg/t_{90}			1		
$N\text{-}NH_{4+}$	mg/L	2		5		
Tot-P	mg/L	2		0.1		
Color	mg/L	825				
Fish toxicity dilution factor				2 (DIN 38412)		

Source: Folke, 1991

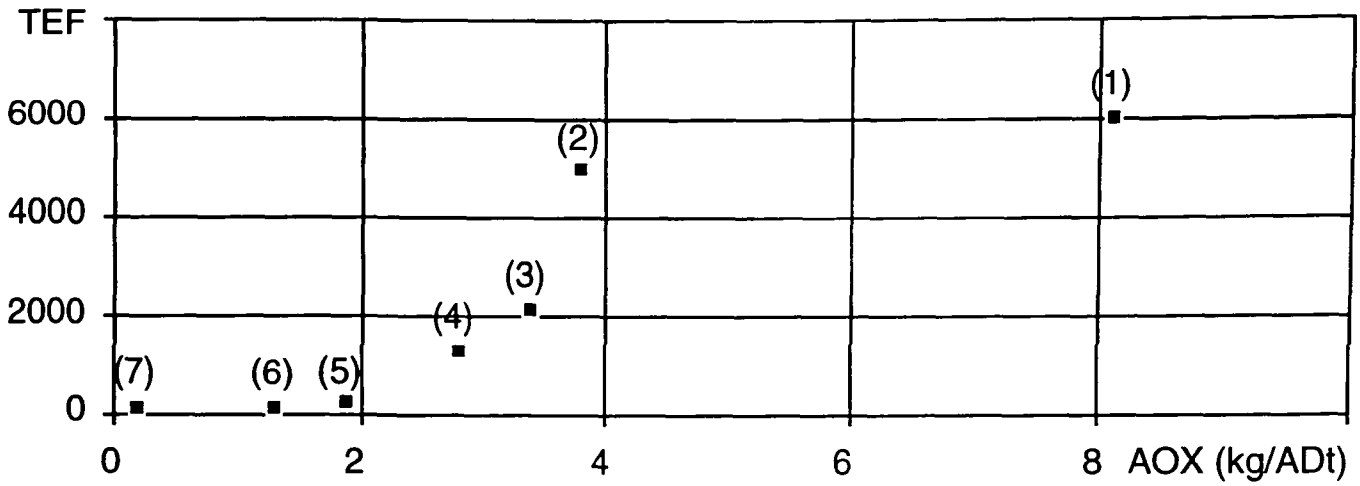
gories, Germany with eight. Spain allows the highest limits for secondary fiber plants.

Swedish Mill Effluent Tests

The biological effects of effluents from Swedish pulp and paper mills using different bleaching and external treatment concepts have been assessed using a variety of biological test methods, ranging from acute lethality tests (to medium-term multispecies tests of subacute or chronic effects) to complex, multispecies tests in outdoor model ecosystems.

A series of medium-term laboratory tests for subacute effects in zebra fish and *Ceriodaphnia* were carried out in which the lowest observed effect concentration (LOEC) was determined for reproduction and survival of embryo/larvae and for induction of adverse effects during gametogenesis in fish, determined as reduced stress tolerance in the offspring (see Fig. 2). Based on data from such tests, one can conclude the following:

- The amount of subacute toxicity, expressed as TEF_{SA} (where TEF_{SA} = 11/LOEC X wastewater flow per ton of pulp) for a mill using a conventional bleaching sequence typical for the years before 1980 is about 1,000 for endpoint A and 6,000 for endpoint B. This serves as a reference for the worst case.
- Introduction of oxygen delignification without any other major change in the bleaching sequence will reduce the TEF_{SA} values to 500 (A) and 5,000 (B). This number represents the technology typical in Sweden around 1985 and now becoming widespread in the United States.
- Reduction of the washing loss and carryover of substance from the oxygen stage to the chlorination stage and better control of the bleaching process, including oxygen reinforcement of the extraction stage (the practice in many Swedish mills at the end of the 1980s) reduces the TEF_{SA} values for the endpoint B to about 2,100 but does not change the TEF_{SA} value for the endpoint A.
- The best available bleaching practice used in Sweden at the beginning of the 1990s, with oxygen delignification followed by a relatively high chlorine charge (70 percent of the active chlorine in the chlorination stage), produces an effluent with TEF_{SA} values of 170 (A) and 250 (B), respectively. Figure 2 shows the reduction of various pollutants in pulp mill effluents as a result of external treatment in an aerated stabilization basin.
- External treatment of the effluents in an aerated stabilization basin with a retention time of 8 to 9 days and operated with an anoxic prezone for effective elimination of chlorate in the effluents, resulted in efficient reduction of most pollutants. Irrespective of the sophistication levels of the washing and bleaching technology, the treatment will produce an effluent that has two to four times lower TEF_{SA} values than effluents before the external treatment. However, the reduction in AOX as a result of the external treatment was normally only 30 to 40 percent as compared with the drastic reduction in toxicity.
- Bleaching sequences with 100 percent substitution and AOX levels of 0.1 to 0.2 kg per air-dried ton do not further reduce the TEF_{SA} values compared with the externally treated effluents (aerated stabilization basin) from mills using the "last-generation" cooking, washing, and bleaching technology, but still keeping a low degree of chlorine dioxide substitution (about 30 percent of the active chlorine in the chlorination stage as D), giving an AOX in the treated effluent of 1.3 kg per air-dried ton.



(1) $C_{95}D_5$ Conventional bleaching (<1980)
(2) O ($C_{85}D_{15}$) (1985)
(3) O $C_{92}D_8$ E(O) (End of 80s)
(4) O $C_{85}D_{15}$ + ASB
(5) O $C_{70}D_{30}$ (Last generation)
(6) O $C_{70}D_{30}$ (Last generation) + ASB
(7) O P D (Modern fluff pulp)

Mills and years refer to the Swedish situation.

Figure 2.—Relationship between AOX and TEF_{SA}.

Adsorbable Organic Halogens

These conclusions are further substantiated by the results of long-term experiments (about 5 months in duration) in which sublittoral brackish-water communities from the Baltic Sea were exposed to various effluents in large (8 m^3) outdoor test tanks. Tank studies were supplemented by medium-term exposures of rainbow trout, followed by assessment of the physiological and biochemical status of the fish.

The combined results from these comprehensive biological tests indicated that no correlation exists between the amount of AOX being formed during the bleaching and the composite biological response. The effluent from a mill producing unbleached kraft pulp produced a composite biological response that was stronger than that obtained with effluents from mills with bleaching and AOX levels up to about 4 kg/ADt. However, the effluents from the production of unbleached pulp are difficult to compare directly with those from bleached production. The only comparison that is justified at this stage is that compounds other than chlorinated organics significantly contribute to the overall toxicity of pulp mill effluents.

The U.N. Conference on Human Environment

Some fundamental principles for the protection of the environment against discharges of pollutants from industrial and other sources were formulated at the United Nations Conference on the Human Environment in Stockholm in 1972. The need for controlling sources of environmental pollutants was reflected in Principle No. 6:

> *The discharge of toxic substances or of other substances and release of heat, in such quantities or concentrations as to exceed the capacity of the environment to render them harmless, must be halted in order to ensure that serious or irreversible damage is not inflicted upon ecosystems.*

This principle is related to "the assimilative capacity" of the environment, which was further developed and given detailed meaning by the Group of Experts on the Scientific Aspects of Marine Pollution in 1986. A clear distinction is made between processes resulting in "contamination" and processes resulting in "pollution." "Contamination" means an increase of substances in the environment as a result of human activities, "pollution" is reserved for substances or heat increases resulting from human activity that result (or are likely to result) in harm or other deleterious effects on living resources and ecosystems, hazards to human health, impairment of environmental quality, and reduction of amenities.

Best Available Technological/ Economical Options

Regulators all over the world tend to adopt the option of best available technology (BAT) or best

available technology economically achievable (BATEA). Quite obviously, however, a stringent and narrow-minded application of this policy will (sometimes) result in suboptimizations of available resources for environmental protection and, occasionally, even in counterprotective action. In particular, the result may be detrimental on the economy and the environment if the BAT policy is uncritically combined with "the principle of precautionary action." If available scientific knowledge is not taken into account, a general and vague fear of possible danger can be used as an argument for requiring action to control inputs of substances to the environment.

Conventional biological wastewater treatment uses heterotrophic microorganisms, ideally to mineralize organics, so that plants can use the material in their photosynthesis. Although such degradation increases the entropy of the environment, it is hardly pollution, because it is necessary for the anabolic activity of plants. Such a degradation process would also occur in nature without the use of biological treatment plants.

The energy that is released through degradation processes during biological wastewater treatment is, in principle, available at the treatment plant. In a very few cases, that energy is used to help drive the process. In other cases, it substitutes more polluting energy sources (see Table 2). However, in most cases, this energy is lost because the capital and maintenance costs of the complex systems that can be used to recover energy (e.g., as gas from sludge digesters) outweigh the costs of purchasing electrical energy from a fossil fuel-burning power station. The use of external (nonrenewable) energy for pumps and aerators results in air pollution resulting from fuel consumption and an overall greater environmental degradation than would be the case without any wastewater treatment at all.

Table 2.—Examples of doubtful investments.

Chlorine dioxide (100% in the first stage)
- uses excess energy as compared to chlorine
- creates a chlor-alkali imbalance
- causes chlorate discharges

Chlorine-free, semibleached pulp (lignox-type)
- uses even more energy than chlorine dioxide
- increases chronic toxicity

Activated sludge treatment for OCl removal
- discharges persistent organics
- uses fossil fuel energy to turn water contamination into air pollution and solid waste

Excessive substitution of virgin fibers with secondary fibers
- virgin and secondary fibers exist in different geographical areas
- "save a tree — eliminate a forest"
- wastepaper collection and processing add to the greenhouse gases more so than wood pulping

Critical Levels of Contamination and Pollution

It is not easy to define the difference between contamination and pollution, but, during the last five years, environmental agencies worldwide have tried to define "critical loads" or "critical levels." The UN Commission for Europe issued the following definition of critical load in relation to transboundary air pollutants:

> *A quantitive estimate of an exposure to one or more pollutants below which significant harmful effects on specific sensitive elements of the environment do not occur according to present knowledge.*

A similar definition may be applicable to specific chlorinated organic substances discharged to the aquatic environment. However, it is not reasonable to assume that the concept of "critical load" can ever be applied to a parameter such as AOX, since AOX comprises a plethora of individual substances with a vast variety of properties. It seems much more promising to try to determine critical loads of specific fractions of the AOX complex — fractions having relatively uniform physicochemical and toxic properties, such as polychlorinated phenolics or polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD and PCDFs).

Protection Strategies

Two useful environmental protection strategies that have been recently developed are based on the "Best Practicable Environmental Option" and "Long-term Sustainability of Receiving Ecosystems." The latter principle was established by the World Commission on Environment and Development in the Brundtland Report, which states:

> *States shall maintain ecosystems and ecological processes essential to the functioning of the biosphere, shall preserve biological diversity, and shall observe the principle of optimal sustainable yield in the use of living natural resources and ecosystems.*

Both principles require a holistic view on environmental problems and imply an optimal use of different environmental media, for example, to accommodate waste with the intent to minimize the overall loading or detrimental effects on the environment. Protection strategies based on these principles will include site-specific environmental quality criteria (or critical levels) with the aim of avoiding local and regional detrimental effects on

ecosystems. The strategies will also include periodic biological field monitoring to check that adequate ecosystem protection is achieved.

External effluent treatment in aerated stabilization basins or activated sludge plants only modestly reduces polychlorinated organics. However, reduction of high AOX emissions by means of internal measures in the mill may represent effective protection of the environment, provided cost-effective and energy-saving solutions are used. The question is, however, how far do we need to go?

The weakness in using AOX as an effluent control parameter in the future is the lack of correlation between the specific AOX discharge and effects on the ecosystems. A modern kraft pulp mill in which the chlorine multiple in the first C/D stage in the bleaching process has been reduced to less than 0.15, corresponding to an AOX formation of 1.5 to 2 kg per air-dried ton, normally produces an effluent with relatively harmless chlorinated organics, which seem to be fairly similar to naturally formed chloroorganics. Nonchlorinated substances, such as wood extractives, are responsible for the remaining weak environmental effects of such effluents. Therefore, a continued strong emphasis on further reductions of AOX below levels of 1.5 kg/ADt is not the best way to provide environmental protection.

Ecological Economics

Environmental protection cannot be examined by itself. Resource production must also be considered. The basic limiting factor in resource production is not currency, but energy and materials required to produce that energy. In only 300 years, humankind will have used (according to some estimates) 80 percent of the entire amount of fossil fuels accumulated over a period of 600 million years. Thus, what is lacking in our current economy is the ability to address properly our use of resources or ecological economics; for instance, to distinguish streams produced from wood chips from streams produced from coal. Pulp and paper mill operations are potentially within the framework of ecological economics.

Pollution control technologies based on using huge amounts of energy are not compatible with ecological economics and should be omitted. The goal is better environmental management of economic activities (see Fig. 3). Seemingly, this is frequently forgotten by environmentalist groups in their push for a better environment.

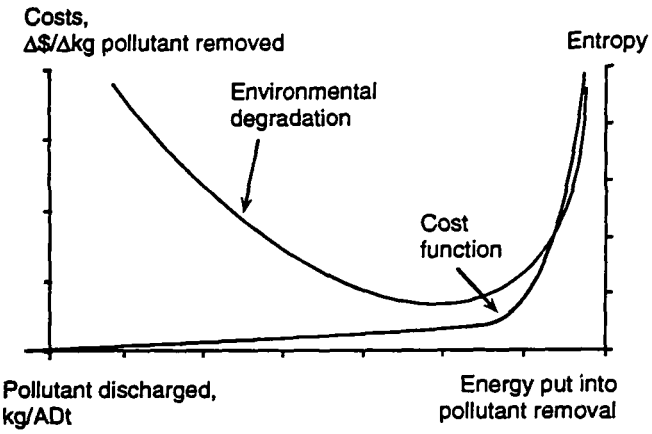


Figure 3.—Maximizing the efforts of ecological economics.

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Environmental Regulation of the United States Pulp and Paper Industry

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Since the mid-20th century, the U.S. pulp and paper industry has invested billions of dollars in ecological enhancement to reduce the unwanted and unintended impacts of its manufacturing processes on the environment. This discussion will briefly describe certain significant regulatory programs and activities now under way, and their implications for the industry and the environment.

Pulp and paper are made from renewable resources, whether from wood, cotton, or other natural fibers, and are among the most environmentally benign products in existence. Paper is recyclable, biodegradable, combustible for energy, and safe for the user. The industry's manufacturing processes, moreover, are in many ways models of pollution prevention. The kraft process, for example, recovers and reuses inorganic chemicals and combusts the organics removed from wood to recover energy. Several closed-loop processes within the mill, such as chemical recovery, the lime cycle, and many water cycles, are designed to use, reuse, and use the same resources again and again.

The pulp and paper industry is among the most capital-intensive industries in this country. This means, among other things, that the industry must respond to ever-pressing demands for major capital improvements to remain competitive; it also means that there is little tolerance for premature obsolescence.

The pulp and paper industry has long demonstrated its commitment to environmental protection and enhancement. A significant event occurred in 1943 — the paper industry's founding of the National Council for Air and Stream Improvement (NCASI) to provide a source of data and information about the environmental effects of the industry's air and water discharges and techniques to reduce them. These observations are very important in considering regulation and regulatory activity affecting the pulp and paper industry.

There are many environmental statutes that affect the industry, both at the State and Federal levels, which impact mill sitings; construction; manufacturing; chemical product use; wastewater discharges; gaseous emissions; solid waste generation, transportation, storage, and disposal; product content, handling, and distribution; human resources issues such as training; and many other factors.

The most significant environmental laws affecting the U.S. pulp and paper industry are the Clean Air Act, the Clean Water Act and the Resource Conservation and Recovery Act. The first two are the most specific to our industry, and are especially important because their scope and impact are not matched by those in effect in other countries.

Clean Air Act

Since 1970, comprehensive Federal legislation and implementing rules have been in place to protect against air pollution's adverse health and welfare effects and to protect aesthetic values such as visibility and odor. The legislation affects new, existing, and modifications of existing sources. New source standards promulgated for major industrial categories are required to be updated every four years. Our industry was one of the earliest to have new source performance standards, which were most recently updated in 1986.

In the United States, the Clean Air Act affects stack emissions as well as fugitive and area sources. It provides a State and Federal framework for achieving and maintaining air quality standards and for preventing "significant air quality deterioration."

Results

Major impacts on the industry's emissions of sulfur dioxide, and particulates including metals, nitrogen oxide (NO_x), volatile organic compounds, carbon monoxide, and total reduced sulfur have resulted. Despite significant industry growth, reductions of 22 percent were achieved in the industry's sulfur dioxide emissions from 1980 to 1985, through decreases in the use of oil and other fossil fuels and in the sulfur content of such fuels.

Control requirements kept increases in the industry's emissions of NO_x to very low amounts. The volumes might otherwise have been large, as a result of increased use of wood residues and coal, for which the NO_x content is slightly higher than for other fuels. Data for 1985–1990 are now being compiled. Particulate controls have resulted in pollution prevention as well as chemical recovery in the industry; but industry-specific figures quantifying the reductions in particulate emissions are not available. However, capture efficiencies in excess of 99.5 percent are typical for new sources or retrofits of existing equipment, compared to the 80 to 90 percent capture efficiencies of the past.

The Clean Air Act, along with industry economics, has spurred increased reliance on internally generated energy (hog fuel and other wood residuals, capture of heat generated in chemical recovery to meet steam requirements, and other steps). An estimated 56 percent of the industry's energy requirements are met through internal energy generation, reducing dependence on fossil fuel, reusing materials, and preventing pollution.

"Air Toxics"

The 1990 Clean Air Act Amendments added sweeping new requirements for "air toxics" regulation that will affect other industry emissions: chlorine, chloroform, hydrochloric acid, methanol, methyl ethyl ketone, and others. The air toxics provisions provide for technology-based emission standards to be established for 189 hazardous air pollutants from major industrial categories of new and existing emitters. These requirements are to be no less stringent than "best-performing 12 percent" for existing sources and to represent the levels achieved by the best performing sources for new installations.

According to the new law's "air toxics" requirements, the U.S. Environmental Protection Agency (EPA) may reduce or eliminate emissions based on process changes, substitutions, enclosures, work practices, operational standards, training, and other means. Strict new rules are expected to be proposed in October 1993, and made final in October 1995.

Clean Water Act

Water pollution control began in the pulp and paper industry almost at the inception of the industry, and has been an earnest matter since the middle part of this century (coinciding with the founding of NCASI) and beyond. These earlier efforts were prompted by local considerations for health and aesthetic qualities.

Since 1972, the United States has implemented comprehensive Federal clean water legislation based on State water quality standards and Federal wastewater discharge standards and limitations. Federal permits are required for wastewater discharges to "navigable waters of the United States," which limit both the content and the mass of the discharges. Provisions have been established to create evolving technology-based standards for each major category of industrial discharger, and also to establish water quality-based limitations aimed at protecting against any potential adverse cumulative impacts due to total loadings.

Like the Clean Air Act, the Clean Water Act reconciles local needs and conditions with environmental protection goals. The rulemaking forum provides the appropriate mechanism for technical review and data compilation, involvement and commentary by all interested parties, and consideration of all relevant factors, such as environmental objectives and impacts, scientific facts and concepts, technology, economics, and timing.

Regulations of the pulp and paper industry under the Clean Water Act have required significant reductions of our industry's discharges of dissolved oxygen, total suspended solids, chemical oxygen demand, biochemical oxygen demand, pH, and conductivity. As a result, well-treated kraft pulp mill effluents operating in compliance with prevailing rules show little or no adverse impact on the environment.

Moreover, there has been a reduction by nearly 95 percent in the amount of biochemical oxygen demand discharged per unit of production since 1945, and by 65 to 75 percent since 1975. There has been a reduction by more than 40 percent of total suspended solids in industry wastewaters per unit of production since 1975, and of more than 80 percent since 1965. Due to water conservation efforts, it required 70 percent less water to make a ton of paper in 1988 than it did in 1959. It is now common in this industry to discharge water with less suspended solid material than was present in the intake water.

Effluent Guidelines Revisions

"Best Available Technology" requirements for our industry are now being updated, as required by the Clean Water Act. Under consideration for both new and existing sources are limitations for dioxin/furan, chlorinated phenolics (which may be regulated as individual compounds or in total), volatile organic compounds, chlorinated organics as in adsorbable organic halogens (AOX), color, and other nonconventional pollutants. "Best Practicable Technology/Best Conventional Technology" requirements are also being updated for conventional pollutants (dissolved oxygen, total suspended solids, chemical oxygen demand, BOD, and pH).

Surrogate substances and measures, such as AOX, are being investigated for use in controlling chlorinated organic compounds. While the industry has long responded to public concern about potential adverse impacts to health and environment attributed to chlorinated organics, the industry questions the appropriateness of a generic regulation not linked to toxicity or other effects. Large amounts of data support the conclusion that few if any adverse impacts occur to the environment that are attributable to this industry's organic chlorinated discharges at today's levels.

Further, the industry does not view the AOX test as an appropriate measure of environmental significance since, among other things, AOX fails to distinguish the "wheat from the chaff" in terms of toxicity of the various compounds that are present, including those also found in nature. In any case, as a result of other pollution prevention efforts (primarily associated with dioxin reductions) a marked reduction in AOX levels has also been achieved. The U.S. industry continues to compare favorably with those of other nations (for example, Sweden, Finland, and Canada). It must be emphasized, however, that no health or environmental rationale justifies the establishment of AOX as a control parameter — a view increasingly understood and shared worldwide.

We would certainly not want to predict the outcome of EPA's effluent guidelines revision, especially before the agency has even proposed the new rules; nevertheless, it is clear that authority exists for EPA to impose stringent new requirements on the industry, that EPA is the appropriate lead agency, and that a proper forum exists for consideration of all relevant factors.

Important Considerations

The pulp and paper industry is capital-intensive, requiring tens or hundreds of millions of dollars each year for new plants and equipment. Capital is scarce and expensive. Effective capital management is a crucial success factor, especially in the United States where capital formation is not supported well by national fiscal policy. Generating returns on investment that are competitive with the financial returns possible in industries that are not capital-intensive is challenging. Foreign competition for our products and investment is also increasing.

Priorities must be established for allocating the limited capital on which the industry can draw in a given year. Constant productivity improvements are critical to survival in a globalized industry. There are of course competing environmental and safety demands — the industry has pledged to advance the rate and technology of recycling; source reduction and pollution prevention initiatives are increasing; and process safety rules, with their pressing goals, also require capital; and there are many other important objectives. Elimination of poverty, enhanced nutrition, and improved delivery of health care cannot be forgotten as part of our urgent national agenda. Given limited resources, choices must be made, and time allotted to generate the necessary capital allowed.

Under the circumstances, stability and predictability in capital requirements are important. This outlook is especially critical for existing facilities, which cannot afford to have technology declared obsolete early in their useful life. Replacement is simply too expensive, and capital is not available. Time for planning for new requirements, and for amortization of existing capital stock, are key.

Therefore, it is imperative that environmental regulations be soundly based, stable, and predictable; reflect appropriate priorities; and allow flexibility to recognize site-specific factors. As a nation, we must aim limited environmental, human, and capital resources at improvements that will bring the most substantial benefits to human health and environmental protection.

Challenges Involved in Effective Environmental Regulation

Developing and implementing effective environmental regulation of this complex and richly diverse industry is a challenge. The industry has existed for hundreds of years, and produces thousands of products using a wide variety of equipment, processes, and chemicals in facilities of all ages and configurations. Establishing rules that will keep all sources moving toward appropriate environmental goals while recognizing their site-specific considerations is a formidable but necessary task.

There are of course encumbrances to compromise, on all sides. The need to maintain a safe, robust, profitable, and responsive industry can make compromise costly. Strict, unyielding legislation and the ties of precedent, coupled with the need to maintain an aggressive profile, can make compromise a difficult legal or political issue for EPA. State and local governments often walk a narrow line, needing strong Federal backing and funding on the one hand but desperate for needed flexibility and discretion on the other. Advocacy groups can at times lose sight of the need for balance, propelled by the need to galvanize public opinion and keep the membership dollars coming.

Difficulties with congressional structure cannot be overlooked. The proliferation of committees and subcommittees, the lack of either a budget or a priority-setting mechanism when it comes to the expenditure of private funds for legislated social goals, and incentives against an organized, measured approach to a goal of any kind have recently created a dizzying collection of conflicting, overlapping, inefficient, and unfocused statutes.

Our only hope of resolution lies in enhanced comprehension among the parties of each other's positions, reliance on scientific and technical fact, and increased public education. Given the present state of the economy, and the mood of the public toward government decisionmaking, these are urgent objectives.

Conclusion

Existing regulations, coupled with massive investments and industry ingenuity, have brought about significant reductions in environmental impacts from the pulp and paper industry. Pollution prevention, spurred by concern for efficiency and economics as well as by regulation, has resulted in recapture and reuse of significant internal streams in the industry's processes. Legislation already in force and its implementing regulations will cause continued environmental improvement as Federal Clean Air and Clean Water Act requirements are implemented and updated. The EPA has ample authority to deal directly with any residual environmental concerns not already addressed by more than 10,000 pages of Federal regulation. There is also the real and growing contribution of voluntary pollution prevention in this industry, as cited by EPA's current Administrator William Reilly. There is no need to resort to distracting, indirect, and distortive approaches such as market intervention to attempt to influence manufacturing, when direct means are readily at hand. The regulatory forum, for all its foibles, remains the last, best hope of determining appropriate environmental protection and pollution prevention goals and the means to achieve them. We all have an interest in improving the process.

U.S. Regional Pollution Prevention Activities

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The Lake Superior Agreement is a United States–Canada program to restore and protect the Lake Superior basin. The agreement, signed in September 1991, established a goal of zero discharge of nine persistent compounds. The International Joint Commission (IJC) had recommended in its 5th Biennial Report that Lake Superior be established as a demonstration area.

The IJC is a six-member binational commission established in 1909 by the Boundary Waters Treaty between the United States and Canada. The commission deals with issues of waters along the border, seeks public and scientific input into these issues, and makes recommendations for action. Two other groups of particular importance to the Great Lakes are the Great Lakes Water Quality Board (made up of State, Provincial, and Federal representatives) and the Great Lakes Science Advisory Board (made up of scientists and technical members).

The Lake Superior Agreement identifies responsibilities of the Federal Governments of Canada and the United States; the States of Minnesota, Wisconsin, and Michigan; and the Province of Ontario. The agreement focuses on zero discharge or emission of nine designated persistent bioaccumulative toxic substances and on a broader program to identify impairments to restoring and protecting the basin's ecosystem. The nine toxics are 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD); octachlorostyrene; hexachlorobenzene; chlordane; dichlorodiphenyltrichloroethane (DDT); dichlorodiphenyldichloroethan (DDE) and other metabolites; toxaphene; polychlorinated biphenyl (PCP); and mercury.

The zero discharge language focuses on a pollution prevention approach and development of a binational plan. A partnership between cities to exchange ideas, strategies, and technical knowledge has been established, and efforts are keyed to the U.S. Environmental Protection Agency (EPA) 33/50 program. The agreement also has special protection designations, including one for enhanced antidegradation.

All of Lake Superior's waters are designated as Outstanding Resource Waters, and areas are identified for no new increases of toxics. The unique characteristics of the lake are recognized. Under the agreement's controls and regulations, point source controls are upgraded, a goal is set for the virtual elimination of toxic substances, and sediment cleanup programs are examined. Consistent standards are sought for the basin, and efforts are made to build on the Great Lakes Initiative.

A broader program to restore and protect the Lake Superior ecosystem is ongoing. It includes an evaluation of the chemically induced impairments in the basin, consistent monitoring programs, and use of a sentinel species as an indicator of basin health. Consistent consumption advisories have been established. Inventory, restoration, and the protection of existing habitats are also being planned. A State of the Basin report is being developed that will include a Lakewide Management Plan.

The protection and restoration program is building on the work performed in seven areas of concern (AOCs) in the basin. This work identifies ecosystem objectives and best management practices (BMPs) for nonpoint source pollution problems.

Joint Pollution Prevention Projects in Three States

Joint projects between Minnesota, Michigan, and Wisconsin, funded by EPA's Great Lakes National Program office, perform the following functions:

- provide a public awareness campaign;
- provide a regional "clean sweep" program for the public in the Duluth/Superior area; and
- train municipal wastewater treatment plant operators to recognize pollution prevention opportunities by increasing their knowledge of local industries.

In Wisconsin, pollution prevention efforts include joint work with the University of Wisconsin Extension Service to provide technical assistance to businesses in the state. A current focus is on hazardous pollutants used in or produced by small- and medium-sized businesses. The joint efforts seek to integrate pollution prevention into existing programs (regulatory and others) and to use all existing communications outlets — newsletters, meetings, and enforcement actions. Permit applications can also be used to request information on multimedia transfers and pollution prevention.

State Actions Affecting Pulp and Paper Mills

Wisconsin's Consolidated Papers, Inc., has established dioxin minimization activities that have improved brown stock washing, expanded chlorine dioxide substitution as much as 45 to 55 percent, evaluated hydrogen peroxide bleaching and oxygen delignification use, and assessed the reduction of air emissions through incineration. The goal of these activities is focused on maintaining a consistent level of dioxin discharge below the effluent limit of 0.73 mg per day.

The Nekoosa Papers–Georgia-Pacific Corporation Dioxin Elimination Project has resulted in the high substitution of chlorine dioxide in the first bleaching stage and the use of hydrogen peroxide in the second stage, substitution of low precursor defoamers, improvement of brown stock washing efficiency, and a stepwise addition of chlorine. The project's goal is a consistent level of dioxin discharge below the level of 0.49 mg per day.

Procter & Gamble has worked with Wisconsin to switch from its current hypochlorite bleaching of broke to the use of Oxone™, a proprietary process of the Du Pont Company, by the of end of 1993, thereby reducing chloroform emissions by 75 percent.

In Minnesota, pollution prevention has focused on the Potlatch Corporation's kraft mill expansion and discharges to the Western Lake Superior Sanitary District treatment plant. The company has worked on doubling its bleached kraft production, installing new brown stock washing systems, adding oxygen delignification systems, and converting to 100 percent chlorine dioxide processes. These changes also include air emission controls. The State expects to see a 46 percent reduction in the discharge of dioxin and other chlorinated organics.

The State of Michigan is requiring minimization of dioxin in all internal waste streams. Michigan is taking a general approach similar to Wisconsin and Minnesota that should result in chlorine dioxide substitution, the careful selection of other chemicals such as defoamers, and the installation of oxygen delignification systems.

For More Information

Wisconsin

- Lake Superior Agreement/Ecosystem
  Charles Ledin
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  (608) 266-1956
- Joint Pollution Prevention Projects
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An Update on Washington State's Hazardous Waste Reduction Act

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A statewide goal of reducing hazardous waste generation by 50 percent by 1995 is in effect in Washington State, based on the Hazardous Waste Reduction Act of 1990, which encourages reduction of hazardous substance use and hazardous waste generation whenever economically and technically practicable. Pollution prevention plans are necessary to achieve the statewide goal. Hence, planning is required by law, while implementation is voluntary. Facilities can be fined for failure to prepare a plan, but they can't be fined for failure to meet reduction goals.

Implementing the Act

So what drives implementation? How are pollution prevention programs adequately established at a facility, and how is reduction really accomplished without regulatory mandate? The answer is good pollution prevention planning. Washington's law establishes certain key elements to be addressed throughout the planning process. By incorporating these key elements, a successful waste reduction program can be put into place. Washington's planning requirements are detailed in WAC 173-307-030 (Wash. Dep. Ecol. 1991). For pulp and paper mills, the plan is organized in four parts:

- **Management Support/General Overview.** The first section must begin with a policy statement that shows management and corporate support for the planning effort. It should provide the policy's scope and objectives; describe the facility, products made, and levels of production; and present an overview of the processes used. Finally, it should present information on total annual pounds of hazardous waste generated and toxic releases, and a description of current reduction, recycling, and treatment activities.
- **Opportunities/Goals/Implementation.** The second section serves to identify hazardous substances used and hazardous waste generated, describe each facility process, and identify all reasonable opportunities for further reduction, recycling, and treatment. It should also evaluate identified pollution prevention opportunities and select the opportunities to be implemented. A policy statement that risks will not be shifted should proceed a list of specific performance goals and an implementation schedule (a five-year plan).
- **Financial Plan Description.** The third section will identify costs and benefits from implementing the selected opportunities. A description of the accounting systems used must also be included.
- **Personnel and Employee Requirements.** The fourth section describes personnel training and employee involvement programs. Employees are encouraged to provide input during the planning process.

The written plan or an executive summary must be submitted to the Washington State Department of Ecology. Most pulp and paper mills in Washington were required to complete plans by September 1, 1992 (a few facilities must complete plans by 1993 or 1994). After this filing, progress reports must be submitted to the Department of Ecology annually on September 1. The progress report should provide exact information on the quantities of hazardous waste and hazardous substances reduced during the prior year.

Technical Assistance

Several forms of technical assistance are available to mills preparing pollution prevention plans. The Northwest Pulp & Paper Association, National Council of the Pulp and Paper Industry for Air and Stream Improvement (NCASI), and Washington Pulp and Paper Foundation have been active in gathering and disseminating information.

Washington's Department of Ecology has a Waste Reduction, Recycling, and Litter Control (WRRLC) program; this program is available to provide technical assistance for meeting the planning requirements. WRRLC's Toxics Reduction Unit works with facilities in completing plans. Staff identify specific pollution prevention ideas and technologies, develop environmental programs, educate management and employees about pollution prevention, or define reduction and recycling opportunities. The WRRLC program is nonregulatory — staff do not conduct inspections or enforce waste management regulations.

WRRLC staff are available to meet with managers to discuss pollution prevention issues. At some facilities, WRRLC has been involved in kick-off meetings to help educate employees about pollution prevention and to assist in "getting everyone on board." They have also helped evaluate unit processes to define reduction opportunities, reviewed existing facility programs for implementation of proposed reduction activities, and helped set up costs-and-benefits tracking systems.

As an integral part of WRRLC's long-term technical assistance to the pulp and paper industry, staff are working with other regulatory programs, organizations, and community groups to define and address pollution prevention barriers.

Regulatory Barriers and Opportunities

One of the primary pollution prevention regulatory barriers that affects the pulp and paper industry is an end-of-pipe, medium-specific focus. Regulatory actions are often geared toward controlling or abating pollutants rather than prevention. Further, regulatory policies such as Best Demonstrated Available Technologies (BDAT) and Best Available Control Technology (BACT) are in many cases based on specific control and management technologies. This type of specification, while effective, "seems to center on a single-medium approach and can potentially reduce flexibility and innovation," as the Minnesota Office of Waste Management (1991) discovered in its *Report on Barriers to Pollution Prevention.*

To further complicate the regulatory scene, the sometimes adversarial nature of the mill/agency relationship is also a primary barrier. For quite some time, regulators have lived in a "command and control" mode; facilities have operated in a "compliance" mode with lawyers as intermediaries. This relationship is often ineffective, and potential advances in environmental management are lost. To address these barriers, WRRLC has initiated a number of projects including the review of the State's solid and hazardous waste regulations and their administration. Regulators and industry have been solicited to define problems. Some of the questions being asked include the following:

- Are regulations appropriate and understandable?
- Do they address pollution prevention?
- Are regulators appropriately interpreting and administering the law?
- Is the administrative system working?
- How can identified barriers be addressed?

WRRLC is trying to enhance cross-program communication and interaction, by working with the U.S. Environmental Protection Agency (EPA) Region X Pollution Prevention Roundtable on a workshop for permit writers, and by working with Department of Ecology enforcement programs to review permit and enforcement actions for the integration of pollution prevention alternatives. Under an EPA contract, WRRLC is currently participating in a project with a local pulp and paper mill to compile a model pollution prevention plan for the kraft segment of the pulp and paper industry. This plan is to be used to settle enforcement actions creatively and to come up with a multimedia approach to pollution prevention planning.

Economic and Institutional Issues

Many mills operate on a limited time for return on investment, and most pollution prevention alternatives are costly and result in little or no added value for the company. To address these problems, WRRLC provides information on available grants, loans, and credits. WRRLC has also been active in developing economic analysis guidelines for pollution prevention, and in compiling and relaying information on total cost accounting. Liability, compliance, and oversight costs are required to be addressed through Washington's pollution prevention planning law. WRRLC provides mills with the tools they need to get a handle on these costs. The Department of Ecology's Water Quality Program Alternative Strategies Unit is investigating economic incentives for water pollution control. Projects are focused on determining efficiency, equity, and feasibility of using various economic in-

centives or market-oriented approaches for water pollution control purposes.

WRRLC has also sought to determine potential incentives for implementing pollution prevention alternatives within the pulp and paper industry. Washington has joined with several other States to form the Western States Contracting Alliance. This purchasing alliance was formed to create market incentives for recycled products, thereby also driving potential pollution prevention activities.

The structures that support agency and mill operation are complex, and communication is tough. Department of Ecology staff members don't always talk to each other and mill managers don't always communicate well internally. The Department and mills don't always speak the same language. Other communication barriers exist between the department and the public, and between mills and the public. Common ground is often difficult to establish, and clear vision is difficult to find. WRRLC is involved in cross-program training and educational efforts. WRRLC staff attend training sessions that are hosted by other Agency programs, and regulatory staff are encouraged to attend WRRLC training sessions. WRRLC encourages cross-departmental activities within mills — forming planning teams to address pollution prevention issues, and modifying or enhancing existing structures to include pollution prevention activities.

WRRLC is also working with pulp and paper associations to gather and disseminate information. For example, this fall, the Department of Ecology and the Northwest Pulp and Paper Association will cosponsor a workshop on boiler ash issues. Interaction is critical. WRRLC understands its need to learn more about how the industry works, how decisions are made, and how external issues affect business decisions so that its members, as members of the regulatory community, can offer a more informed response to regulatory issues. WRRLC interaction with industry associations and mills allows for that sort of education.

Conclusion

Many issues and activities are currently being explored in the area of pollution prevention. It seems that our interest in pollution prevention could easily be focused on one issue such as chlorine bleaching vs. nonchlorine bleaching. This effort does lead to great breakthroughs; however, focusing solely on pollution prevention technology can be misleading. Pollution prevention deals more with the goal of technology than its content and is rarely advanced by adding a black box to an operational process. Instead, pollution prevention involves finding innovative ways to look at processes and operations. We need to move beyond our own comfort to work in a more productive way with mills and government agencies. We need to work more productively to share information among the separate worlds of industry, community, and regulators.

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British Columbia Regulations to Eliminate Adsorbable Organic Halogens from Pulp Mill Effluents

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British Columbia has 24 pulp mills, which play a significant role in its economy. Most of the mills produce chlorine bleached kraft pulp, from softwood, for an export market. Pollution from British Columbia's pulp mills has been one of the province's most serious environmental issues, and the subject of heightened public concern. Recently, the British Columbia government has received widespread attention because of its tough new pulp mill regulation, put into effect July 1, 1992, that requires mills to eliminate adsorbable organic halogens (AOX) that are produced in the bleaching process by December 31, 2002.

The regulation gives each mill a choice. It can opt to meet an interim discharge standard of 1.5 kg AOX per air-dried metric ton (tonne) of pulp produced on or before December 31, 1995; in that case, the mill has until the end of 2002 to eliminate AOX entirely. Alternatively, a mill can bypass the interim standard of 1.5 kg AOX, and choose instead to eliminate it entirely by December 31, 2000. All mills were required to submit plans and schedules by June 30, 1992, indicating how they would meet the new standards. Progress reports will be required every six months.

The new AOX limits follow the 1990 introduction of organochlorine regulations in British Columbia. At that time, the British Columbia government set a limit of 2.5 kg AOX per air-dried tonne of pulp and also required all mills to have secondary treatment facilities installed. Each mill negotiated a date to meet these requirements, since a number of mills needed substantial upgrading to meet the standards.

Events Leading to Regulation

In 1988, following reports linking dioxins to pulp mills, the Canadian government conducted dioxin analysis of shellfish collected near three coastal pulp mills and, several months later, closed coastal shellfisheries near those mills.

Since late 1988, the Federal Government has closed hundreds of kilometers of British Columbia's coastline to shellfish harvesting in nine major areas because of dioxin and furan contamination from pulp mills. These shellfisheries' closures were accompanied by a number of health advisories, which warned people not to consume certain species of fish over set limits, and some types of diving ducks and waterbirds. A general advisory was issued against eating the livers of any bottomfish caught near coastal mills.

The closures and the health advisories created concern in British Columbia among industry, government, and the public. In addition to the environmental concerns, many shellfishers lost their source of livelihood when the shellfisheries were closed. Aboriginal peoples, who often live close to pulp mills, lost a major source of food.

Since 1988, mounting public pressure about pulp mill pollution, dioxin contamination, the shellfisheries' closures, and the continuing discharge of organochlorines from pulp mills led to two major responses from the government. Both the Provincial and Federal governments have significantly tightened the environmental standards that apply to pulp mills, and the Provincial government has started seriously prosecuting offending

pulp mills. Until recently, the British Columbia pulp and paper industry had a history of routine noncompliance with regulatory standards. Now it is not uncommon for a mill in violation of environmental standards to be prosecuted.

The Pulp Pollution Campaign

I am a lawyer with the West Coast Environmental Law Association (WCELA), a nonprofit public interest organization in British Columbia that provides legal advice and legal counsel to individuals and organizations with environmental problems. Since 1988, lawyers at WCELA have acted on behalf of 54 individuals and organizations representing over 250,000 citizens, who have been concerned about pollution from pulp and paper mills in British Columbia. We call this the Pulp Pollution Campaign.

WCELA also participates in a multisector group called the Multi-Stakeholder Working Group (MSWG) on Pulp Mill Regulation in British Columbia. This group was formed in 1991 to provide imput to the pulp mill regulatory process in the Province. The MSWG includes a wide variety of stakeholders, including individuals from environmental groups, unions, native peoples, the pulp and paper industry, shellfish associations, technology suppliers and consulting engineers, the Federal Government, the Provincial Government, and universities.

Universal Aspects of British Columbia Regulations

Pulp mills are also regulated throughout Canada by the Federal government. The Canadian Environmental Protection Act prohibits mills from discharging detectable levels of dioxins and furans after January 1, 1994. The federal Fisheries Act governs the discharge of the conventional pollutants — biochemical oxygen demand (BOD), total suspended solids (TSS), and toxicity. It also requires mills to participate in an environmental effects monitoring program, which helps determine whether or not the current regulatory standards are adequate to protect the environment.

Most British Columbia mills have undergone major upgrading because of the changes in pulp mill regulations over the last two years, and because of high level public and industry concern in the Province about pulp mill pollution. It is clear that the most recent regulation requiring the elimination of organochlorines by 2002 will continue to drive the development of technology needed to meet that standard.

There are four aspects of the British Columbia regulation requiring the elimination of organochlorines that can be applied anywhere in the prevention of pulp mill pollution. The regulation

- incorporates precautionary and preventative approach principles;
- uses long-term planning;
- targets a goal of zero pollution; and
- takes advantage of emerging market opportunities.

Precautionary and Preventative Approach Principles

The precautionary principle — that action should be taken to prevent contamination before there is conclusive proof of harm — is receiving significant attention in the quest for sustainability. Many scientists and policymakers have pointed out the dangers of waiting for proof of harm before taking action to cut pollution. To quote the Great Lakes Science Advisory Board (1989):

> *The current requirement for "proof" of harm creates a situation that can resolve itself only through costly errors. One by one "proof" of harm can never keep pace with the rates of introduction of chemicals.*

Likewise, Gro Bruntland, Prime Minister of Norway and former chair of the U.N. Commission on Environment and Development states:

> *I will add my strong support to those who say that we cannot delay action until all scientific facts are on the table. We already know enough to start to act — and to act more forcefully. We know the time it takes from decision to implementation to practical effects. We know that it costs more to repair environmental damage than to prevent it. If we err in our decisions affecting the future of our children and our planet, let us err on the side of caution (Cameron and Abouchar, 1991).*

This precautionary approach is in contrast to the traditional approach of allowing the release of pollutants until it is proven that a particular pollutant is harmful to humans or the environment. Only then do governments respond by regulating the harmful substance. This traditional approach ig-

nores how little is really known about the multitude of pollutants that are released into the environment and the complex web of life that such pollutants affect.

In the past when we have discovered serious environmental consequences from members of the organochlorine family, such as dichlorodipheny/trichloroethane (DDT), polychlorinated biphenyls (PCBs), and dioxins, we have gone through painful — and expensive — environmental catch up as we learn about the environmental damage and embark on the slow process of implementing regulatory standards to deal with the substances.

Using the precautionary approach rather than the traditional one to develop regulations makes sense if we are serious about achieving sustainability. Where there are threats of serious environmental damage, lack of scientific certainty should not be used as a rationale for postponing measures to prevent that damage.

There has been discussion about the scientific uncertainties associated with using AOX as a regulatory tool. The elimination of organochlorines is not the same as choosing a permissible discharge level. Requiring the elim-ination of AOX indicates a policy decision to err on the side of caution in the face of scientific uncertainty. It also signals to industry that a process change is required to eliminate the use of chlorine compounds in bleaching pulp.

Preventing the production of organochlorines opens up the possibility of eliminating the discharge of all pulp mill effluent. Eliminating the use of chlorine compounds will remove many of the problems associated with recycling the effluent from kraft mills.

Organochlorines are not responsible for all environmental problems associated with pulp mill effluent. For example, research by scientists at Environment Canada suggests that pulp mill effluent affects fish, even when the effluent is from a pulp mill that does not use chlorine compounds.

The process changes needed to eliminate organochlorines could enable the pulp industry to more easily become effluent free, solving both the organochlorine problem and any other known — or unknown — environmental problems associated with pulp mill effluent.

Increasing emphasis is placed today on the "polluter pays" principle, namely, that those who pollute should pay the ensuing costs and damages. In British Columbia, many parties have called for compensation for the victims of pulp mill pollution, particularly in light of the shellfisheries' closures. In this context, the precautionary principle and the preventative principle are the least expensive approaches to dealing with pulp mill pollution.

Long-term Planning

The regulatory approach taken by the British Columbia government incorporates long-term government planning. Recognizing that sustainability involves planning the future as well as cleaning up the past, the British Columbia government has enacted a law more than 10 years in advance of when the requirements must be met.

The 10-year period for achieving the elimination of organochlorines allows industry a realistic time frame for developing and implementing the process changes that will be necessary. The AOX regulation requires that mills report on their plans every six months, showing progress toward achieving the long-term requirement. The government intends to involve all sectors in discussing the plans for process changes and in monitoring the progress of the industry. Clearly, if we have a long-range plan, we can choose process changes that will yield the maximum environmental benefits, and we will also have time to assess the potential environmental impacts of new processes.

Goal of Zero Pollution

The government recently released an Environmental Action Plan for British Columbia, which states, "Our goal is zero pollution." This standard provides the benchmark against which all regulatory initiatives aimed at environmental protection can be measured. The elimination of organochlorines goes some distance in achieving that standard for the pulp industry.

Market Opportunities

Given the growing global interest in purchasing pulp bleached without chlorine compounds, the British Columbia regulation helps its pulp and paper industry to anticipate and meet that market demand. The industry knows that it will be required to produce such pulp within a time frame of 10 years. Therefore, industry is in a good position to seek out and to cultivate the market for environmentally benign products.

Sustainability in the pulp and paper sector will involve radical shifts in approaches to pollution and significant process changes to achieve a goal of zero pollution. The British Columbia regulation requiring the elimination of organochlorines is a step in that direction.

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Panel 4:
Government Activities

Question and Answer Session

■ **Phil Berry,** *Oregon Department of Environmental Quality:* I'd like to ask Mike Witt about some things. One very quick question about the integration of pollution prevention into NPDES permits. We've been working as an organization to integrate pollution prevention into all the things that we do that include permitting. I'm curious if Wisconsin has found any ways to integrate specific pollution prevention approaches into NPDES permits.

■ **Michael Witt,** *Wisconsin Department of Natural Resources:* There are several ways to approach permits. One way is to put in study requirements, which we've done in a number of permits, by asking people to take something like an environmental audit approach to their process. Some people call these "waste minimization studies." Then, to follow up, we've asked those who set specific dates to provide submittals. That's about as far as we've got. I could come up with a few other examples, but they aren't really representative of the program as a whole.

■ **Gayle Coyer,** *National Wildlife Federation:* A quick comment and then a question. My comment is directed to Dr. Folke. I think the problem with your regulatory framework and your designations of contaminants and pollutants is that contaminants turn into pollutants. I mean, who would have thought when we started discharging the contaminant DDT that it would become a devastating pollutant. Or who would have thought that the contaminant PCB would turn into a devastating pollutant? I think that we need to reverse the onus: chemicals are guilty until they're proven innocent, instead of innocent until they're proven guilty.

■ **Jens Folke,** *Environmental Research Group, Denmark:* The ecotoxicological signs for DDT and PCB have been developing over the last 35 years, and are now quite advanced. I think you are perhaps disregarding the scientific knowledge that has been gained in these ecotoxicological signs when you come up with these examples to indict other chemicals.

■ **Gayle Coyer:** My question is for Mike Witt, regarding the Lake Superior Binational Program. I think it represents a historic precedent that two Federal governments, three states, and a province have gotten together and actually committed to protect a particular body of water. In that respect the program represents a good example for the rest of the nation. My concern is to make this program mean more than just paper, particularly in the realm of controls and regulations and permits. It has to be a truly coordinated effort around the lake. It is also a first chance for these governments to tell us what their zero discharge commitment was in the Potlatch Corporation expansion permits, and for us to ask where Michigan and Wisconsin were during that whole process. Where was the EPA? Did the EPA discuss whether or not the agency agreed with the Minnesota decisions or even if these decisions were compatible with a commitment to zero discharge?

■ **Michael Witt:** The response, Gayle, is that we recognized this problem early in the summer and met a few times with representatives from the other states to work it out. I think we have relatively better communication on permit issues now than we had even four or five months ago. I'm hoping that it

helps. I know that you'll watch us to see that it does.

■ **Gayle Coyer:** Are we going to see a coordinated response on the Murphy Oil Permits?

■ **Michael Witt:** We have communicated with the other states on that issue. I hope that we will have better communication and better involvement before it's too late. As you know, once we get down the road, it's tough to turn around and go a different direction. We're looking for earlier opportunities and consistency in approach so that if we go one direction, the state of Michigan or Minnesota won't go off in a different direction with a permit, or something like that. It's going to take a little time, but I think we're putting the pieces into place now to get coordination in the future.

The Pulp and Paper Cluster's Mission

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The Pulp and Paper Cluster group, formed by the U.S. Environmental Protection Agency (EPA), has a four-part mission:

1. To coordinate development and implementation of rules, guidance, and action affecting the industry, with a special emphasis on minimizing cross-media (air, water, and soil) impacts.
2. To conduct outreach to the industry, environmental groups, and the public generally about EPA activities affecting the industry.
3. To try and improve management efficiencies inside the agency; to share data collection and analyses; to combine our rulemakings; and to reduce and eliminate redundant work among various programs.
4. To encourage the adoption of pollution prevention techniques in the industry. This final goal is one of EPA Administrator William Reilly's priorities, and the reason that the Pulp and Paper Industry Cluster sponsored this conference.

The Cluster started in the summer of 1990 with the involvement of three EPA offices — Water, Toxic Substances, and Policy Planning and Evaluation. Now eight EPA program offices are very active in the Cluster. They include the Offices of Water, Air, Solid Waste, General Counsel, Policy Planning and Evaluation, Regional Operations, Research and Development, and Enforcement.

The EPA Regions participate as needed and many of them plug into our meetings by teleconference. Some regional personnel occasionally attend Cluster meetings and provide support for the headquarters' staff.

The Cluster is now focusing on several major regulations, including the revised Effluent Guideline for the water program. Another is the Maximum Achievable Control Technology (MACT) rule that John Sietz, Office of Air Quality Planning and Standards, will discuss. A third is the pulp and paper mill sludge rules that are the shared responsibility of Jeff Denit, Office of Solid Waste, and Mark Greenwood, Office of Pollution Prevention and Toxics. They will talk about that rule.

Changing hats, now, from the Cluster to the Water Program, I will speak briefly about activities going on in the Office of Water.

Clean Water Act

The 1987 Clean Water Act amendments spurred many States to adopt toxic standards very quickly — States that had not previously had ambient water quality standards for toxic pollutants. Forty-two States and territories have moved to adopt dioxin standards by setting numeric criteria that span four orders of magnitude in their degree of stringency. The States have shown considerable flexibility in what they can do. Of the 42 standards that have been adopted, EPA has approved 39. A total of 48 of the 57 states and territories now have dioxin criteria in development, proposed, or adopted, and EPA has proposed dioxin standards for the remaining States.

Information about the permitting program is current as of June 30, 1992. Fifty-one final permits were issued to pulp and paper mills that discharge to streams identified as "toxic hot spots." EPA and the States were required to address these streams on an expedited basis under section 304(l) of the Clean Water Act. Nineteen of the 51 final permits were issued by EPA, 32 by the States — all with dioxin limits. Eight more permits are in development. At least another 51 pulp and paper mills discharge waste to other waterbodies not on the list of "toxic hot spots." These 51 mills have final permits

that include dioxin limits or dioxin-monitoring requirements — three have EPA permits, 48 have State permits. Seven additional permits are currently in draft form.

Many of the final 51 permits are in the appeal stage of the 304(l) process. In all, 39 have been appealed. Five permits not falling under section 304(l) have been appealed. Almost all of the EPA permits have been appealed. State laws vary, but under Federal law when an appeal is filed, the challenged provisions are stayed until the appeal is resolved.

Effluent Guideline

EPA is required to propose a revised Effluent Guideline regulation by October 1993. This revision is on schedule with the terms of a consent decree that settled a lawsuit filed by the Environmental Defense Fund and the National Wildlife Federation against EPA. Three key Office of Water people are working on those regulations; they are Don Anderson, Debbie Nichol, and George Heath.

EPA has decided to develop the pulp and paper effluent guideline and the Maximum Achievable Control Technology (MACT) rule concurrently. We recognize that circumstances could arise to delay one or the other of these rules, and that we are operating under mandated deadlines. If circumstances should arise to delay one or the other, we will have to decide whether it makes sense to keep the two processes concurrent. At present, however, that is our goal, and we are on schedule. The results should assure industry that the requirements for air and water will be developed together and should improve industry's ability to plan expansions and pollution prevention, and to respond to concerns by the public, environmentalists, and government.

Moving the Effluent Guidelines and the MACT rules forward simultaneously will improve our chances for the highest net environmental gain at the least cost and reduce EPA's cost in developing the rule. Under the current schedule, we will meet with EPA's Deputy Administrator in April 1993 to discuss options on the rules, after which our offices will complete the draft version of all analyses and rule language by August 1993. Finally, the draft should be in proposal form by October 1993.

The proposed regulation will reflect EPA's consideration of the range of available technologies. For bleach mills we will look at technologies ranging from improved housekeeping to improved pulp washing to chlorine dioxide substitution, oxygen delignification, hydrogen peroxide substitution, and combinations of these. We may also need to look at some add-ons to meet specific water or air regulations. The Effluent Guidelines establish performance standards; they do not stipulate technologies for effluent treatment or manufacturing. We do look at these technologies, however, to determine appropriate limits.

Our greatest difficulty right now is keeping up with the technological changes at U.S. pulp and paper mills. At least half of all U.S. pulp mills have made significant changes in the last few years. EPA is watching these changes as closely as possible, to make sure our final rule reflects the latest information. We are considering whether or not to have a public hearing sometime this fall, perhaps on the joint process that we have undertaken. We would be interested in your response to these ideas.

The Pulp and Paper Sludge Rule

Mark Greenwood
Director, Office of Pollution Prevention and Toxics
U.S. Environmental Protection Agency
Washington, D.C.

Under Section 6 of the Toxic Substances Control Act (TSCA), the U.S. Environmental Protection Agency (EPA) Office of Pollution Prevention and Toxics (OPPT) set standards and management practices for land spreading sludge, and proposed a rule in May 1991. In October 1991, the EPA's risk assessment materials on the sludge rule were peer-reviewed. The peer reviews that came back were critical in many ways, but that was expected because this is a precedent-setting risk assessment that deals with many complex issues, including avian risks. The comment period closed at the end of November 1991, and we are now in the process of deciding what to do next.

The comments we received indicate that we need to consider new data related to Section 308 of the Clean Water Act. We also learned to our concern that EPA is having a significant impact on the role of various State programs that manage sludge, and that the proposed rule would affect the distribution and marketing of some products. We had to start thinking through options for how we might deal with the issues in this area.

The third problem (regarding marketing and distribution) is closely related to the title of my office and this conference. We are concerned about the way the sludge rules may play into industry incentives for pollution prevention. Our current thinking is that we will need to repropose the rule, which probably won't happen until the fall of 1993.

The time lag may be negative for us but at the same time it represents an opportunity. By delaying the final rule until October 1993, we will be on track with the timelines for air and water. Thus, we may be able to create a more integrated analysis of how the sludge management option fits into the technological choices that are presented in the air and water rules. The delay will also allow more time to look at risk reduction. One option we are considering is whether we should approach the industry about sludge management in the short term.

The 33/50 Program

Talking about a voluntary approach is a good segue into the 33/50 program, which is an innovative way of approaching a pollution problem. Every year, EPA looks at emissions on the Toxic Release Inventory (TRI) and we find that some emissions are relatively high in many industries. We decided to lower the emission levels and to find an innovative way of getting industry to do so. In 1991, EPA Administrator William Reilly wrote letters to the CEOs of major U.S. companies that emit high levels of toxicants, and asked them to make commitments to reduce their emissions of 17 key chemicals by 33 percent in 1992 and by 50 percent in 1995. There were no sanctions associated with participation or nonparticipation — it was totally voluntary. Overall, industry response has been positive. More than 850 companies made commitments to the program to reduce their emissions by 350 million pounds by 1995. This reduction is significant. It's rare to get 850 companies to do anything in concert. EPA is pleased with the 33/50 results.

How does the pulp and paper industry fit this scenario? We approached 7,700 companies initially, of which 156 were paper companies (paper and pulp manufacturers and other sectors of the paper products industry). In 1988, pulp and paper industry plants emitted 84 million pounds of the 17 TRI chemicals, or about 6 percent of the total. By 1990, the TRI emissions from this industry had been reduced to 65.9 million pounds — a 22 percent reduction in two years.

Of the 156 paper companies, 40 joined the 33/50 program with explicit numerical commit-

ments — a commitment rate of 26 percent. That is a very high response rate. The industry should be complimented for that. Only the pharmaceutical industry and pesticide manufacturers had a higher rate of response. The 40 companies committed to the 33/50 program account for 68 percent of the industry's total waste generation — a rather significant portion of the industry. This response indicates that your industry is making a good-faith effort to participate in voluntary programs as well as regulatory programs. I commend you for this effort, and if any of you are interested, the 33/50 program is still open.

The Maximum Achievable Control Technology Rule

John S. Seitz
Director, Office of Air Quality Planning and Standards
Office of Air and Radiation
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina

To develop a Maximum Achievable Control Technology (MACT) Rule, there is a process by which we collect information. Working with industry, we take the best 88 percent mark that current technology can accomplish in air emission reduction as the "MACT floor" for existing sources. In addition, for new sources, we can take the best of the best, and base the MACT standard on that. We do have some options in setting a technology standard. Most standards equate to a performance level that is ascertained by collecting data, sharing information, understanding that information, and setting a target.

In the past, the U.S. Environmental Protection Agency (EPA) set a standard in the air program that industry felt was very rigid and provided no flexibility. Industry also told EPA that the water standard was in contradiction to the air standard — causing the industry to spend many thousands of dollars to comply with the water standard, only to find out later that other standards made that expenditure premature and wasteful.

In terms of process, the MACT standard, the Cluster activity, and the effluent guidelines address this problem head-on. The standpoint in the Office of Air is that the MACT rule and effluent guidelines lead us down the regulatory path together. It would be a tremendous disservice to the industry, to the environmental community, to State and local agencies, and to the Federal regulators to be forced to deal with the various pollution requirements for this industry in isolation from each other. We are trying very hard to integrate these activities because separate statutory mandates could pull them apart. I feel very strongly that they need to stay together.

My office will meet the October 1993 deadline for the effluent guideline. The Office of Air staff experts who are working on this project are Penny Lassiter and Stephen Shedd. We are working very hard to meet this commitment and have assigned additional people to this project to meet the water schedule.

On the surface, we have what appears to be a very simple task, namely, to set a technology-based standard, subcategorize its components, and establish the "MACT floor." But what we need to talk about among all interested parties is *how* to set a technology standard that fosters and gives industry the flexibility and incentives it needs to follow up on pollution prevention opportunities. How does the EPA Office of Air assure the public and environmentalists that the industry's technology standards meet the intent of the Clean Air Act, if you choose to go an alternative route? How do we set a standard that States are able to write into a permitting program?

We have gone very public in implementing the Clean Air Act, and we intend to keep the MACT regulatory process as public as we can. To collect up-to-date data and to share information, we want to meet frequently with industry, environmentalists, State and local regu-lators, and the public. If I have a question about MACT implementation, I want to be able to ask industry what its concerns are and how can we work this out together.

For the past year, we have been in close contact with industry as we implemented the Clean Air Act, and we have been very successful. My professional staff feels strongly that this communication process allows us to propose better regulations than would

otherwise be possible. As we move to integrate these two rules, I challenge us to continue to work together. I was not here earlier today but I understand that Dee Williams (Washington State Department of Ecology) said she heard and felt the polarization in the room. The challenge in implementing the Clean Air Act, is to continue to communicate actively with all parties despite disagreements.

I hope that spirit of open-ended communication is kept alive, as we continue to meet on these topics. The National Air Pollution Control Techniques Advisory Committee will be meeting early next year, and we invite everyone to attend.

Solid Waste Office Update

Jeffery Denit
Deputy Director, Office of Solid Waste
U.S. Environmental Protection Agency
Washington, D.C.

The Office of Solid Waste at the U.S. Environmental Protection Agency (EPA) is substantially involved in the Cluster activities established by Hank Habicht, U.S. EPA Deputy Administrator. Within the past year, EPA's discussions on sludge disposal in land-fills benefited immensely from the input of the Cluster organizations. With their help, EPA determined that the risk to human health and the environment does not justify national regulations and that local authorities are adequate to address any risks. Another activity involving the Office of Solid Waste is the land spreading of sludge and its effect on wildlife and human health. Some extremely difficult issues are associated with exposure assessments and this sludge disposal rule. The Office of Solid Waste will continue to be involved in this rule as necessary.

The most significant impact of the Resource Conservation and Recovery Act (RCRA) on the pulp and paper industry in the short term may be EPA's Municipal Subtitle D program, which will have implications for commodity recycling. Pulp and paper products constitute 40 percent of the municipal solid waste stream. We see it as our responsibility to establish national leadership in designing a high priority, solid waste management program.

Our overall approach is to stimulate the supply of recyclable materials and the demand for recycled products, including paper. The Federal Paper Procurement Guidelines require dealing with several complex issues, including a thorough understanding of the guidelines associated with government procurement and their application in private sector purchasing. How do we cope with the general notion of recycled content — including pre- and postconsumer materials and total recycled content? There are many extremely complicated issues involved with something as large-scale as the Federal Government's procurement of paper and paper products.

Later this fall, a focus group meeting will be held to gather additional input from all interested parties on how Federal Paper Procurement Guidelines can be revised. We will, of course, issue a Federal Register notice announcing the anticipated establishment of the group. Other initiatives include partial funding for the National Office Paper Recycling Project, directed by the U.S. Conference of Mayors which recently issued a national challenge to business and industry to increase the collection of recovered paper and the use of recycled paper products. EPA is an active participant in both arenas. In the meantime, we continue to provide technical assistance to other Federal agencies as they implement their recycling programs. EPA is currently preparing a guidebook on the introduction and use of recycled products.

Regarding Subtitle D nonhazardous wastes, and the pulp and paper industry's wastes in particular, EPA is already working closely with several key States that are essential actors in regulatory matters affecting industrial wastes. Wisconsin and Alabama have been included in this instance, because of the pulp and paper industry's presence in those States. EPA is also conducting an analysis of pulp and paper sludge to better determine whether sludge can be a recycled product.

Panel 5:
EPA Activities

Question and Answer Session

■ **Mark Floegel,** *Greenpeace:* I just can't leave the microphone alone. I'm like an ant in the sugar. These remarks are not a question or a comment but a proposal. And I'm going to make it to this panel because it seems to be the most appropriate. I know that one of the goals of this conference is to achieve even-handedness among the disparate groups that are together here, and in that light, you've put out some beautiful conference materials. I've noticed, however, that they're all on chlorine-bleached paper. I propose that the proceedings for the conference be done on chlorine-free paper and then people will have some of both when they look back on the conference. There are a number of people here, I know, who produce or sell such papers. I'm sure they could set you up with something that would meet your specifications and your budget.

■ **Mark Greenwood:** I guess we'll see how competitive their prices are.

■ **Martha Prothro,** *Office of Water, U.S. Environmental Protection Agency*: Actually, there is a reason behind our choices. I'm not sure if we want to go into it now, but it did occur to us before the conference to use both. It's not as easy as you may think. *

Are there any other questions? Comments?

■ **Jessica Landman,** *Natural Resources Defense Council* (microphone not on): When you meet to discuss Federal procurement guidelines, will you be discussing the issue of chlorine-free paper?

■ **Mark Greenwood:** No, I expect the issues of process technology to be discussed. At this juncture, I don't really know the degree to which we'll discuss the issues of chlorine-free vs. not chlorine-free. Our primary statutory directive is to worry about recycled content. That's what our principal focus will be, because it certainly represents the main issue for us at this point.

■ **Jessica Landman:** I respectfully suggest that in your collective responsibilities under the Pollution Prevention Act of 1990 you do have an opportunity and an obligation to look at other cross media issues. It would seem to me like a logical opportunity to put such questions on the table.

■ **Mark Greenwood:** I have no doubt they'll be put on the table. I'm not suggesting they won't be.

■ **Jessica Landman:** One final question about that. To whom will the procurement guidelines be applicable? To EPA alone or to others outside EPA?

■ **Mark Greenwood:** Federal procurement guidelines are broadly applicable to agencies of the Federal government and others who may use them. Incidentally, I don't know if most of you know this, but I think it is fairly significant that the *Congressional Record* will now be printed on 100 percent recycled paper, effective May 1, 1992.

* See Conference Note on page 339.

Thursday, August 20, 1992

PRODUCT PERFORMANCE SPECIFICATIONS AND CUSTOMER DEMAND

PANEL 1: **Direct Customers**

PANEL 2: **Publishers and Printers**

LUNCHEON SPEAKER: **The Implications of Sustainable Development for the Forest Product Industry**

PANEL 3: **Market Pulp**

CLOSING REMARKS

The Market for Chlorine-free Paper

David Assmann
Vice President and Director of Information Services
Conservatree Paper Company
San Francisco, California

Markets for any new product are driven by demand and supply-side considerations. We need to look at both in order to determine the future of chlorine-free paper.

Demand Side

The pressures responsible for creating a demand for paper produced without chlorine or chlorine derivatives are driven by health and environmental concerns. Dioxin was first found in paper mill sludge in 1985, and the U.S. public first became aware of dioxin content in paper in 1987. Since then, public concern about organochlorines in paper has been building steadily.

Two years ago we got one call a month asking about chlorine-free paper — now we get calls virtually every day from potential consumers of chlorine-free paper. Whether or not the messages that are getting through to consumers and paper users about organochlorines are 100 percent accurate isn't the issue — the very fact that they are part of consumer perception makes them market considerations. The concerns we hear most frequently are these:

- **Organochlorines and dioxins are a health hazard at any level.** From the U.S. Environmental Protection Agency (EPA) report (1985) that called dioxin "the most potent carcinogen ever tested on laboratory animals" to this summer's media reports calling dioxin "an environmental hormone that can disrupt the immune system and induce a variety of cancers," consumers are getting the message that dioxins and, by extension, organochlorines are dangerous. Recent media reports have even called into question the practice of chlorinating water.

- **Organochlorines pose a hazard to wildlife.** Interest in chlorine-free paper increased at the end of last year after widespread media coverage of a U.S. Fish and Wildlife press report that dioxin had been discovered in the eggshells of bald eagles nesting near the lower Columbia River in Oregon (see also R.G. Anthony et al. In press). On March 24, 1992, the *New York Times* reported that gulls and seabirds exposed to organochlorines by eating contaminated fish are suffering reproductive damage that is similar to the effects of diethylstilbestrol (DES), the now-banned drug that resulted in serious health problems for the daughters and sons of women who used the drug in the 1950s (*New York Times,* 1992).

  It has also been reported that organochlorines pose a threat to the health of wildlife in the Great Lakes. The International Joint Commission, a U.S.–Canadian commission charged with monitoring the health of the Great Lakes, has recommended that the use of chlorine and its compounds be avoided in the manufacturing process (Int. Joint Comm. 1992).

- **Organochlorines are a hazard to the ozone layer.** James Anderson, a Harvard physicist who headed a major atmospheric study for the National Aeronautics and Space Administration (NASA) has called for an end to the production of chlorine and bromine compounds because they have a negative effect on the global ozone layer. NASA's study disputes a long-held notion that chlorine and bromine play a minor role in controlling ozone concentrations (Natl. Aero. Space Admin. 1992).

These concerns will continue to drive consumer demand for chlorine-free paper. Consumer demand will also be augmented by public and private policy initiatives that grow out of consumer concerns. So far these initiatives include a decision

by British Columbia, Canada, to ban all organochlorine emissions by 2002. The province of Ontario has already banned the production of dioxins and furans in petroleum manufacturing and is now looking at doing the same for pulp and paper.

State preference programs for chlorine-free paper are proliferating. For example, Oregon is considering a 12 percent price preference for chlorine-free paper. A number of State officials are now on record as having called for the elimination of chlorine bleaching. Governor Howard Dean of Vermont has even appealed to New York state officials to force International Paper to switch from chlorine to oxygen bleaching to eliminate organochlorine contamination.

Increasingly, municipal, State, and Federal price requests are specifying chlorine-free paper. The U.S. General Services Administration is currently trying to determine the availability of chlorine-free paper, and a 17-state buying consortium has included chlorine-free paper in its requests for bids.

Industry is also responsive to consumer needs. The editors of *Time* magazine, in a statement issued after they had received 22,000 letters complaining about the magazine's use of chlorine-bleached paper, have said that *Time* will switch to chlorine-free paper when it becomes available. A major copy chain, Kinko's, will soon offer chlorine-free papers in all its stores across the country.

Supply Side

Unfortunately, the supply of chlorine-free paper is not keeping pace with the demand. Although the paper industry has had patents for chlorine-free bleaching technologies since the early 1970s — one of these patents described chlorine bleaching as a cause of serious pollution as early as 1970 — it has been slow to implement any chlorine-free processes in North America.

Twenty-six mills are listed as producing totally chlorine-free market pulp in the March 1992 issue of *Pulp and Paper International,* and another 10 are listed as studying totally chlorine-free processes or carrying out trials, but none of these are mills are in the United States (O'Reardon, 1992). As far as we know, the only two manufacturers of chlorine-free printing and writing paper in the United States are Lyons Falls and Mohawk. The amount of chlorine-free paper currently available in this country is minuscule.

It's not that chlorine-free paper can't be produced here. In other parts of the world, chlorine-free paper is being made in many grades, including lightweight coated paper. European mills produced 500,000 tons of chlorine-free paper in 1991 and will be producing 4.5 million tons a year by 1995.

Many North American mills have substituted chlorine dioxide or other chlorine derivatives for chlorine gas (also known as elemental chlorine). This substitution can significantly reduce the emission of organochlorines, but it does not eliminate the production of these toxins. However, their continued production hasn't stopped companies from trying to exploit the switch to chlorine dioxide. Mr. Coffee, for example, claims that its chlorine dioxide-bleached coffee filters are produced using a "chlorine-free" process. But, as *Consumer Reports* (1991) notes, "chemists would be hard-pressed to explain how a method using any chlorinated compound can be chlorine-free."

The American Paper Institute (API) has mounted an aggressive campaign against chlorine-free paper. For example, when the General Services Administration sent out a request for information on chlorine-free papers to paper companies, the Institute sent a memo (Horton, 1992) to all its members, saying that they were not obligated to respond to the request for information about chlorine-free papers.

The memo, signed by API's Virgil Horton, makes this statement:

> *Last week I alerted you that a questionnaire the General Services Administration (GSA) prepared on recycled content and bleaching processes might be mailed to your company. It is important for you to know that you are not required to respond to this questionnaire in total, or in part. The GSA has no government mandate requiring this information.*

This resistance to chlorine-free paper comes despite concrete evidence that there is consumer demand for, and interest in, chlorine-free paper.

Five years ago, in 1987, API commissioned a public opinion poll — one which, to this day, they have not made public (*Cambridge Reports,* 1987).

According to this poll, when the public was asked, "if dioxin is discovered in paper products at extremely low levels, would you cut back on your use of paper products," 59 percent said yes. Another 10 percent said they weren't sure. In other words, more than two-thirds of the population would reduce their consumption of paper in order to avoid contact with dioxins.

That same poll shows that only 10 percent of the public would find a scientist employed by a paper company to be credible on the dioxin issue.

That percentage drops to 7 percent in States that produce paper, and paper company presidents rank even lower than company scientists.

That's the crux of the issue. The public is not going to believe an industry that offers chlorine dioxide as a substitute for chlorine.

Of those polled, 48 percent believed that action should be taken to keep dioxin out of the air, water, and soil — without any further study. Given the negative media dioxin has received in the past six months, that percentage is probably higher today.

Despite industry resistance, I believe the supply of chlorine-free paper will increase as a result of (1) increasing consumer and corporate demand for chlorine-free papers and (2) regulatory and legal actions to limit the production of organochlorines. The paper industry has already been hit with hundreds of lawsuits over dioxin contamination, some of which have resulted in multimillion dollar jury awards. Insurance carriers for paper companies have also stipulated that they will not cover jury awards for dioxin contamination.

The North American paper industry needs to recognize that chlorine-free paper is the future. In Europe, the pulp and paper industry has already come to that conclusion. In an article in *Pulp and Paper International* last August entitled "Chlorine is Dying: We Told You So," the publication editorialized that "reports of the death of chlorine are far from exaggerated. In the short term, that means the death of elemental chlorine, but let's be clear, over the next 10 years, we are talking about the removal of the whole chlorine family of compounds from the pulp-bleaching process" (Pearson, 1991).

In April of this year, *Pulp and Paper International* ran a follow-up editorial:

> *There are still many companies which would reject the Nordic rush into TCF (totally chlorine-free). They argue that chlorine is still innocent of any damage to human health until such time as this can be proven. They also believe that the investment needed to remove traces of compounds which are actually harmless puts too high a cost on a currently unprofitable industry like market pulp. They do not envisage a headlong rush into TCF, but gradual elimination of molecular chlorine and a substitution of chlorine dioxide.*
>
> *Foremost among these voices is Georgia-Pacific in the USA, which told its customers at the end of January that it had invested heavily in fundamental research into the chlorine issue and had reached the conclusion that substituting chlorine by chlorine dioxide was the way forward, not complete chlorine removal.*
>
> *It's not difficult to sympathize with GP's view. But in our opinion it has brought forward its argument too late. The debate with the environmentalists put the pulp industry on the defensive three years ago and planted some ideas about the industry in the minds of the consumer. The clock cannot be turned back.*
>
> *What all researchers into organic chlorine compounds can agree about is that little is understood about how organochlorines behave in the human body. All that seems to be known is that they are difficult for the body to eliminate, and can be accumulated in fat tissues. With the science in this formative stage, the potential for scare stories which will disrupt the business of the chlorine-using pulp industry is enormous. Market pulp producers using chlorine and its compounds are in danger of remaining on the defensive for a long time to come.*
>
> *For that reason, we believe that the tide will sweep the market pulp industry towards the final elimination of chlorine bleacheries. Whether or not you believe that organochlorine effluent from pulp mills is harmful to humans, a failure to respond to the rising environmental tide of the 1990s could well lead to an ebb in your company's fortunes (Pearson, 1992).*

Chlorine is Not the Only Pollution Issue

As important as the chlorine issue is, it is not the only pollution issue connected with paper production. Other issues include sulphur and other air emissions, the use of solvents in deinking, landspreading of paper sludge, paper incineration, and pollution reduction through the use of recycled paper.

Incineration, which is now being marketed as waste-to-energy, competes directly with recycling for the 80 percent of the waste stream that is both burnable and recyclable. "Waste to energy" plants recover from 1 to 10 percent of the energy value of solid waste, while recycling typically recovers between 50 and 90 percent. According to the American Paper Institute, 60 percent of the annual release of dioxin comes from the incineration of municipal solid waste. In addition, incineration

releases other organochlorines, nitrogen oxides, sulfur oxides, carbon monoxide, and hydrogen chloride.

Recycling, on the other hand, keeps pollutants out of the air, in addition to saving energy, water, trees, and landfill space.

Despite the industry's claims that they're doing everything they can to promote recycling, we lag behind much of the rest of the world in recycling. Our recovery rate is lower than the global average, and lags behind countries like Chile, Colombia, and Bulgaria. If the industry meets its target of 40 percent recovery in 1995, we'll have a wastepaper utilization rate of 30 percent. That's still 23 percent lower than the rate we had in 1944. If we look at printing and writing paper — the largest single paper component of the solid waste stream — we're currently recycling less than 6 percent of this paper. Less than 1 percent of postconsumer printing and writing paper gets recycled back into printing and writing paper.

Meanwhile our collection programs are outpacing demand. We'll collect 250,000 more tons of office paper than we can use this year. No wonder wastepaper prices have dropped by 42 percent since 1986.

Rather than build new deinking facilities, the industry continues to expand virgin paper capacity. Over the past decade virgin paper capacity in the printing and writing field has grown by 8 million tons, while deinking capacity has actually shown a decrease. In 1976, 13 recycling mills had their own deinking facilities producing high grade printing and writing paper. By 1990, eight of these had closed.

In conclusion, the industry has a long way to go to eliminate chlorine and chlorine derivatives, to promote the production of recycled paper, and to reduce pollution overall.

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Life in a Medium-sized Paper Company

John F. Church, Jr.
President
The Cincinnati Cordage and Paper Company
Cincinnati, Ohio

The Cincinnati Cordage and Paper Company, headquartered in Cincinnati, Ohio, is an independent printing and writing paper merchant operating warehouses in Cincinnati, Dayton, Columbus, and Cleveland, Ohio; Indianapolis, Indiana; Huntington, West Virginia; Knoxville and Nashville, Tennessee; and Pittsburgh, Pennsylvania. We also have retail locations in Pittsburgh, Youngstown, Akron, and Cleveland. We have sales people who call coast to coast on publication and catalog business, and we have a sales specification program throughout the corporation. We consider our company to be fairly representative of the industry, notwithstanding the enormous multibillion dollar merchants and the small single location houses among our competition.

Paper Use

In 1991, we purchased approximately $120 million worth of paper, in the amounts listed in Table 1.

We serve 6,000 customers a year, with 130,000 orders. Today, 5 to 7 percent of our papers are made with recycled content; 10 years ago that figure was 1 percent or less.

Our product specifications are generally accepted as industry standards. They vary slightly from mill to mill and grade to grade but are always competitive. We do develop special grades from time to time to meet specific customer needs, but these, too, fall within industry norms. Some specialty grades that are manufactured on a regular basis have become standards — for example, the latex papers, Texaprint and Kimdura. The brightness range on our papers is from 60 to 99 and the opacity range is from 80 to 99, in general. Other papers exist that are obviously translucent sheets, and others that are less bright and opaque, but they are generally not used by our customers.

The papers we purchase are made by a variety of technologies. Alkaline is becoming the standard paper grade because of its archival qualities, cost, and quality. Approximately 30 percent of the papers we now purchase are alkaline, and we estimate that this figure will grow to 60 or 70 percent in five years.

Table 1.—Paper stocks purchased by Cordage Papers in 1991 as a percent of total papers purchased.

PAPER GRADES	PERCENT	
Coated book	18.3	
Web coated	16.1	
Offset	14.1	
Coated cover	11.0	
Bond	7.8	
Xerographic	7.2	
Carbonless	5.8	
Subtotal		80.3
Envelopes	3.1	
Text	2.7	
Opaque	2.3	
Text cover	2.0	
Pressure sensitive	1.5	
Uncoated cover	1.0	
Index	1.0	
Subtotal		13.6
Other	6.1	
Total		100.0

Traditionally, paper merchants have had a close and critical relationship with suppliers, and through franchise and other agreements, we represent our suppliers in the marketplace. Sometimes this commitment goes beyond market force, but at the end of the day, the marketplace itself decides what products are purchased and manufactured, and the customer reigns as king. We market, promote, specify, and stock the papers that make the most sense to us and help fulfill our obligation to our customer and suppliers. We cannot stock everything. We are driven by the needs of our stakeholders: our customers, suppliers, employees, stockholders, and the community in which we work and live.

Customer Description

In our market niche are commercial printers, quick printers, in-plant printers, publishers, institutions, nonprofit and government agencies, major corporations, business forms printers, and converters. Sensitivity to environmental issues varies dramatically from group to group and within each group. Commercial printers and business forms manufacturers are moderately sensitive to environmental issues, in general, but very sensitive when operating in an environmentally high impact area, where emissions are of great concern. The industry is improving the manufacturing process and developing water-based and soy-based inks. Environmental awareness and interest are on the rise.

Quick printers are much smaller businesses and their interest is generally modest at best. It is primarily driven by their customers' needs and desires, with an occasional exception. In-plant printers are motivated by the wishes of their corporate owners and the motivation for large corporations is the same. The consumer-products companies that have a high profile are most interested in the environment. They seek to convey a very positive corporate image to the consumer, which includes environmental responsibility.

Publishers' paper needs vary dramatically based on their publication's content and readership. Magazine publishers are usually more sensitive, and in this group *Buzzworm* is the most environmentally enlightened and committed publisher I know as far as recycled paper is concerned. Others are extremely focused on costs. The price gap severely restricts companies from switching to recycled papers, especially in tough economic conditions. Institutions have a strong interest in environmental issues, but their efforts to change are often hampered by cost considerations. Institutions, especially hospitals and educational institutions, have a responsibility to all their constituents. Nonprofit and government agencies, however, seem to have the strongest interest of all — understandably. Converters' interest depends on their manufacturing process and product line. They tend to be more interested if they perceive a marketing advantage.

A great deal of confusion over the past several years has centered on recycled papers — their definition and the integrity of their fibers, quality, and price. I would ask our industry to confirm the objective. Is it to reduce or eliminate solid waste to the landfill? If so, the old adage "waste not, want not" applies.

The customer demand for alternatively bleached paper is very low; however, confusion about the bleaching issue is extreme. Most customers don't understand the issue and appear not to care. But we provide information on the issue to customers who request it and seek alternatively bleached products for these customers whenever possible. Dioxin has only recently become a focus now that newly developed testing equipment has been able to detect low levels of the substance in paper. Totally chlorine-free (TCF) bleaching is not an issue at this time because there are so few mills that offer TCF papers. A demand for TCF papers will no doubt grow, although very slowly. Cordage Papers will support TCF mills as they develop, and work with them to create successful marketing programs.

If there is one thought I would like to leave with you, it's the need for balance. I found it best stated in the August 17, 1992, issue of *Walden's Paper Report*. Eight state co-ops have bought 15,700 tons of recycled paper. They are going to form a standards board to set common specifications for manufacturers, based on "a pragmatic decision balancing the desire to achieve high percentage of recycled content with the need to insure that the standards can be reasonably achieved at economically feasible prices." The same balance can be achieved with TCF.

Pollution Prevention — How Customers View the Issues

Donald G. Monefeldt
Manager, Supply Products Marketing
Xerox Corporation
Webster, New York

Xerox, a major reseller of xerographic paper around the world, got into this business because the existing grades of office paper were not well-suited for use in a xerographic copier. A cooperative effort between Xerox and one of its suppliers lead to the development of the xerographic grade. Today, about 3 million tons of xerographic grade papers are manufactured annually in the United States.

Xerox continues in the business, however, because we believe that our quality process provides our customers with papers that, on average, significantly outperform the rest of the industry's product.

Xerox is a leadership company — in terms of its products and the way we conduct business. Such leadership must, of course, include environmental responsibility. As an employer, a neighbor, and a supplier, Xerox is concerned about the environment. Part of my job assignment is to help define and implement the company's environmental program as a supplier of toners, developers, and paper products.

Based on input from our customers and our own personnel, we decided that it was critical to assess two environmental areas concerning paper. The first area was the health risks associated with dioxin in the papers produced and the effluent discharged by our suppliers; the second was the feasibility of recycled content xerographic paper.

Customer Interest Level

Over the past few years in the United States, we have only had about 100 customer inquiries about 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) levels in either the paper or the effluent. A few have come from State and local governments. Most come from environmentally concerned individuals seeking information. We have had only a few customers asking us to supply totally chlorine-free (TCF) paper. Our opinion is that customer interest in TCF or elemental chlorine-free (ECF) products is about where recycling was a few years ago. We think it will grow.

The situation in Europe is quite different. Rank Xerox markets two brands of Green paper. One is TCF; the other is an "environmental" paper that carries the Norwegian Foundation's "Swan" label. The Swan label includes parameters for adsorbable organic halogens (AOX), chemical oxygen demand (COD), sulfur, packaging, and fiber sources. These papers are premium-priced niche products. The price premium is in the 15 percent range. Customers are primarily northern European governments and government-regulated companies. The rest of the orders are from a wide spectrum of companies, including some very large companies that also have a significant presence in the United States.

Pappas, an international consulting firm in the United Kingdom, predicts that by 1995 "the market will be almost exclusively chlorine-free." Our Rank Xerox associates expect that half the xerographic grades will be chlorine-free by 1995.

Focus on Recycled-content Papers

In North America, we have had a substantial customer interest in recycling. The total number of inquiries is well into the thousands. Most of our callers wanted information that would help them decide how they should structure their recycling program — in terms of collection and procurement. The modest but growing customer demand for recycled content xerographic papers will grow sig-

nificantly as recycled prices approach parity with virgin paper prices.

We have chosen to focus our efforts on recycling. Before we made that decision, however, we made an attempt to understand the level of health risk associated with TCDD. Regardless of limited customer interest, if we had found convincing evidence that dioxins posed a significant health risk, we were prepared to encourage our suppliers to invest in alternative bleaching processes.

Our environmental health and safety group conducted a survey of the literature in late 1989 and early 1990. They concluded that available published data does not indicate that mills discharging TCDD in the 10 parts per quadrillion (ppq) range constitute a significant health risk. The discharge levels from our suppliers are in the nondetect or low ppq range.

Our research and development team also supports this assessment. They also brought to my attention the fact that paper mills play a very small role in total TCDD generation. Therefore, if one wants to make a meaningful difference in this area, the paper industry is not a prime candidate.

Given that advice, we focused our attention on the recycling issue, where our industry could play a significant role. It is fair to ask, "How did our customers feel about our choice of which issue to pursue?" I think it is accurate to say that they understood our decision but were still uneasy. When the word "dioxin" is used, responses based on risk assessments and detection levels do not cause the anxiety to go away. Dioxin is an emotionally charged topic. That reaction has not changed in two years.

When we made our decision to focus on recycling, our expectation was that the paper industry would eventually move to new bleaching processes; it would just be a matter of time. If for no other reason, customer concern would result in the choice of new bleaching technology for new capacity or regularly scheduled upgrades and rebuilds of existing capacity. We did not expect that the industry would prematurely retire existing capacity that was operating at the nondetect level.

In 1990, we did not have a consensus in our company about how the recycling issue would be resolved. We needed better understanding of three factors regarding the use of waste paper as a raw material for xerographic copy paper. These factors were economics, function, and appearance.

After a considerable amount of work, we concluded that copy paper made from recycled fiber can be cost-effective under certain conditions, but the supply of waste white office paper would have to increase and the price to the mills would have to decrease. The capital investment would have to be made to provide incremental pulp capacity to supply an up-to-date and cost-effective paper machine. Mills that consistently make good quality xerographic paper from virgin fiber would also learn to make good quality paper with the appropriate amount of recycled fiber.

We have qualified some mills to make a recycled content xerographic paper for us. We need to find others.

Facing the Future

Growth in recycling has a positive role to play in pollution prevention. Deinked white office waste requires significantly less bleaching than virgin fiber. One bleaching stage is sufficient in that case. Peroxide is used in at least two U.S. bleaching installations. While I have not seen the numbers, my expectation is that recycling will also get high marks in terms of "eco labeling" criteria.

If I were *Star Trek's* Spock and relied entirely on logic, I would be optimistic about the near-term future for pollution prevention in pulp and paper because of continuing investment in recycling capacity and periodic upgrades of the older bleaching operations to new technology.

But the situation could change quickly and dramatically. The "D" word, dioxin, still generates strong emotional responses. Public interest could grow quickly. Last week, there were two one-hour programs on a Rochester, New York, television station dealing with the effects of pollution in the Great Lakes. Programs like these do get your attention.

I am personally very grateful to the sponsors of this symposium. It is a marvelous learning experience. Based on what I have learned, I believe that my company and the paper industry are doing the right thing. But I must tell you, I have some lingering uneasiness.

I do not envy the people in our industry who will be responding to the two TV programs I saw last week. They need ready access to good data and help to convey the right messages. They — and we — need peer-reviewed data that all parties can support. With the hard data in hand, perhaps there will be other conferences to deal with the questions "What processes are on the right track?" and "What processes have to be changed?"

The Nation's Number One Paper Purchaser Looks at Recycled Content, Chlorine Processing

Barbara Belasco
Environmental/Recycling Spokesperson and Specification Manager
General Service Administration, Region 2
New York, New York

The Federal Government is the United States' single largest consumer of paper products. The General Services Administration (GSA) Federal supply service is the procuring arm of the Federal Government. GSA buys a wide variety of commonly used commodities, among them paper and paper products. GSA does the contracting, then makes the products available to all Federal agencies. Large-volume items are stored in warehouses. GSA also advertises items in publications sent to other agencies. New products can be introduced into the Federal supply system by a request from a vendor, a request from a customer, or initiated by GSA.

In 1991, GSA purchased an estimated 323,000 tons, or $317 million worth of paper and paper products. Estimated tonnage figures for the high volume items were

- xerographic paper: 109,000 tons;
- computer paper: 78,000 tons;
- tissue products: 36,000 tons;
- envelopes: 11,000 tons; and
- fine and printing papers: 12,000 tons.

We also purchase other types of paper, including bond, writing, offset, ledger, mimeo, duplicating, cover, index, computer paper, and products such as envelopes, fax paper, file folders, paperboard, labels, writing pads, napkins, toilet paper, towels, shipping cartons, and wrapping paper.

The best estimate is that we have 35,000 to 40,000 customers, based on a recent survey of activity address codes. Our biggest customer is the Department of Defense.

More than 100 specifications apply to the paper products purchase, and many paper customers have detailed physical, visual, and performance requirements. For example, the xerographic paper specification A-A-1912 requires certain qualities of stiffness, tear, opacity, color, smoothness, and performance, among others. Almost all specifications for paper and paper products have been revised in recent years to include requirements for recycled content.

With a goal of increasing postconsumer content, GSA sent a market survey to 66 paper companies who manufacture printing and writing grades, to study the availability of high grade printing and writing paper made with postconsumer recovered materials. The results showed that each grade was available with 10 percent postconsumer content, in some quantity. Several grades are available with more than 10 percent postconsumer content. In 1991, recycled products accounted for more than $100 million in purchases. The products met or exceeded U.S. Environmental Protection Agency (EPA) requirements for recycled products as listed in *EPA Guidelines for Paper and Paper Products,* 40 CFR Part 250.

Recently, a few customers have requested paper made without chlorine bleaching. Accordingly, we surveyed industry to determine the availability of nonchlorine bleached paper. The responses indicated that some nonchlorine bleached paper is available in the marketplace. GSA is now reviewing the possibility of adding such products to its supply purchases, provided that the cost is reasonable.

The government can create markets for environmentally friendly products. An Agency customer recently requested nonchlorine bleached

copier paper, containing 100 percent waste paper, including 20 percent postconsumer. We responded by putting forth a solicitation for more than 2,000 tons of paper meeting this description. Assuming that we receive bids with reasonable prices, a contract could be awarded, and the paper will be available for the customer. It will also be advertised in government publications to other agencies in order to stimulate demand for this product.

The Federal Government has also responded to environmental groups. Last fall, congressional hearings were held by Senators William S. Cohen (R-Maine) and Carl Levin (D-Michigan) to review the efforts of GSA in environmental areas. Environmental groups testified at these hearings. They were extremely critical of GSA's lack of initiative in the purchase of chlorine-free paper. In response to these hearings, we revised specifications for tissue products — napkins, towels, and toilet tissue. The new specifications require that the products contain 90 to 100 percent postconsumer recovered materials and be unbleached, or totally chlorine-free. This requirement created a new product line of tissue products offered to our customers as alternatives to the standard products. The napkins have been in the GSA warehouse for several months and are available for purchase by our customers. They are included in the GSA catalog and have been advertised in *MarkeTips*, the government advertising magazine that is sent to all agencies. Awards for towels and toilet tissue will be made shortly. Specification changes were made to allow for the purchase of postconsumer, unbleached tissue products.

Customers are very aware of the critical issues surrounding solid waste. Recycling and the procurement of recycled products have been stimulated by the Resource Conservation and Recovery Act (RCRA). Customers are willing and eager to buy our recycled products. GSA publishes a recycled products guide, a listing of all recycled products. On the other hand, interest in non-chlorine bleached paper is relatively new. As a purchasing agency, we have to be responsive to customer demands and know what is available in the marketplace. As we have worked with industry on recycled products, so will we work with industry to satisfy our customers' demands for paper products made without chlorine bleach.

Pollution Prevention in the Envelope Industry

Michael J. Cousin
Mail-Well Envelope
Georgia-Pacific Corporation
Atlanta, Georgia

Georgia-Pacific's Mail-Well Envelope is proud of its record of success in pollution prevention. We are a leader in safe manufacturing processes and the efficient use of raw materials. Pollution prevention and associated waste reduction strategies are a fundamental component of the way we do business. Our successes are permanent and a building block for future improvements because they make economic sense.

Mail-Well produces envelopes. Paper must be available to satisfy our customers' quality and price demands. The availability of high volume, low cost paper for use in the production of envelopes is requisite for the long-term viability of the envelope industry. Reclaiming fiber is a sound business approach to this long-term goal. Specifying the composition of specific performance paper products is not; it raises costs and does not provide a long-term solution to the diminishing availability of landfill space. Reusing fiber for energy is an exciting alternative for paper that cannot be economically reclaimed.

The scenario for so-called chlorine-free papers is similar. Specifying the use of totally chlorine-free (TCF) pulps will only add to the manufacturing cost and limit the availability of high volume papers. TCF is prohibitively costly as a kraft bleaching process. The older sulfite process is a limited option for TCF approaches; however, sulfite pulps have lower inherent strength than kraft pulps. The tradeoff in strength is unacceptable for use in performance papers. In addition, bleached sulfite pulp accounts for only a small fraction of the available bleached pulp. If a nonchlorine bleaching sequence is a better alternative than shutting down a sulfite pulp mill and paying higher prices for market pulp, then the paper price will also be higher.

A combination of effective management approaches and technological innovations that satisfy the cost and quality criteria for world class, competitive industries is a winning strategy. Progress in the use of flexographic printing and water-based inks is one example of a successful pollution prevention strategy.

The envelope industry has focused on the appropriate selection and efficient use of raw materials as its most effective pollution prevention strategy. Mail-Well remains a leader in the eyes of its customers because it has not sacrificed quality to any management or technological approach. We continue to produce the products that our customers want at the quality standard they need and expect and at competitive prices.

Envelopes

The envelope industry purchases approximately 1.15 million tons of paper annually. Thus, envelope papers accounted for approximately 10 percent of the 11.5 million tons of uncoated free sheet papers shipped in 1991 (Am. Pap. Institute, 1992a).

According to calculations from data collected by the Envelope Manufacturers Association of America (EMAA), approximately 50 percent of the cost to produce envelopes is the cost of raw materials. As much as 80 percent of this cost is for paper; the rest is distributed among ink, adhesives, and window film purchases. Raw materials reclamation for internal use or for outside sale is a critical component of the business strategy of envelope manufacturers.

Paper

According to U.S. Postal Service (USPS) data, approximately 15.2 billion pieces of first and third class mail were processed in 1991 (Am. Pap. Institute, 1992b). This figure reflects a 2.6 percent

compound annual growth rate since 1986. And according to information provided by the U.S. General Services Administration (GSA), envelopes with recycled fiber account for 27 percent, or approximately $18 million of the $67 million of GSA's annual envelope purchases. By contrast, recycled uncoated free sheet accounted for only 6 percent of all uncoated free sheet shipped in 1991. In today's low demand economic climate, government purchases appear to be a major force in the sale of envelopes made from recycled paper.

Commercial envelope purchasers require price parity between recycled and virgin papers — a cost parity that we are nowhere near achieving. This discrepancy presents a barrier to the accessibility of recycled papers for use in high volume performance paper products. Recycled papers cost more to produce than virgin papers, and the incentive for papermakers to invest capital in collection, sorting, cleaning, deinking,, and bleaching equipment will not materialize so long as these prices do not reflect costs.

Recycled Paper Availability

Figure 1 presents a comparison of the relative costs to produce a ton of paper on various machines currently operating in the United States. The market price for envelope papers reflects their manufacture at lower cost, high volume, world-class papermaking facilities. Paper is produced using pulp supplied by on-site mills integrated with fast, wide, and efficient modern paper machines. Any strategy that increases the costs to produce products at these facilities will inhibit their ability to compete profitably in the world's markets for high volume, price sensitive products such as envelope papers. In fact, the costs to produce paper must continue to go down if existing firms hope to compete against the newer, larger machines that are added each year. Simply maintaining costs is not good enough to assure a manufacturer's long-term growth.

Many older U.S. papermaking facilities require more fiber than can be produced from their on-site pulp mills. Consequently, these partially integrated facilities purchase market pulp to satisfy their fiber requirements. The machines at these mills tend to be smaller and less productive than their modern counterparts.

The higher operating costs of these facilities require a manufacturing strategy that promotes the production of higher priced products to generate the returns necessary to stay in business. Although mills with smaller machines — those in the middle range of Figure 1 — still attempt to compete in the envelope papers market, the manufacture of envelope papers, whether virgin or recycled, cannot be considered a long-term strategy for them.

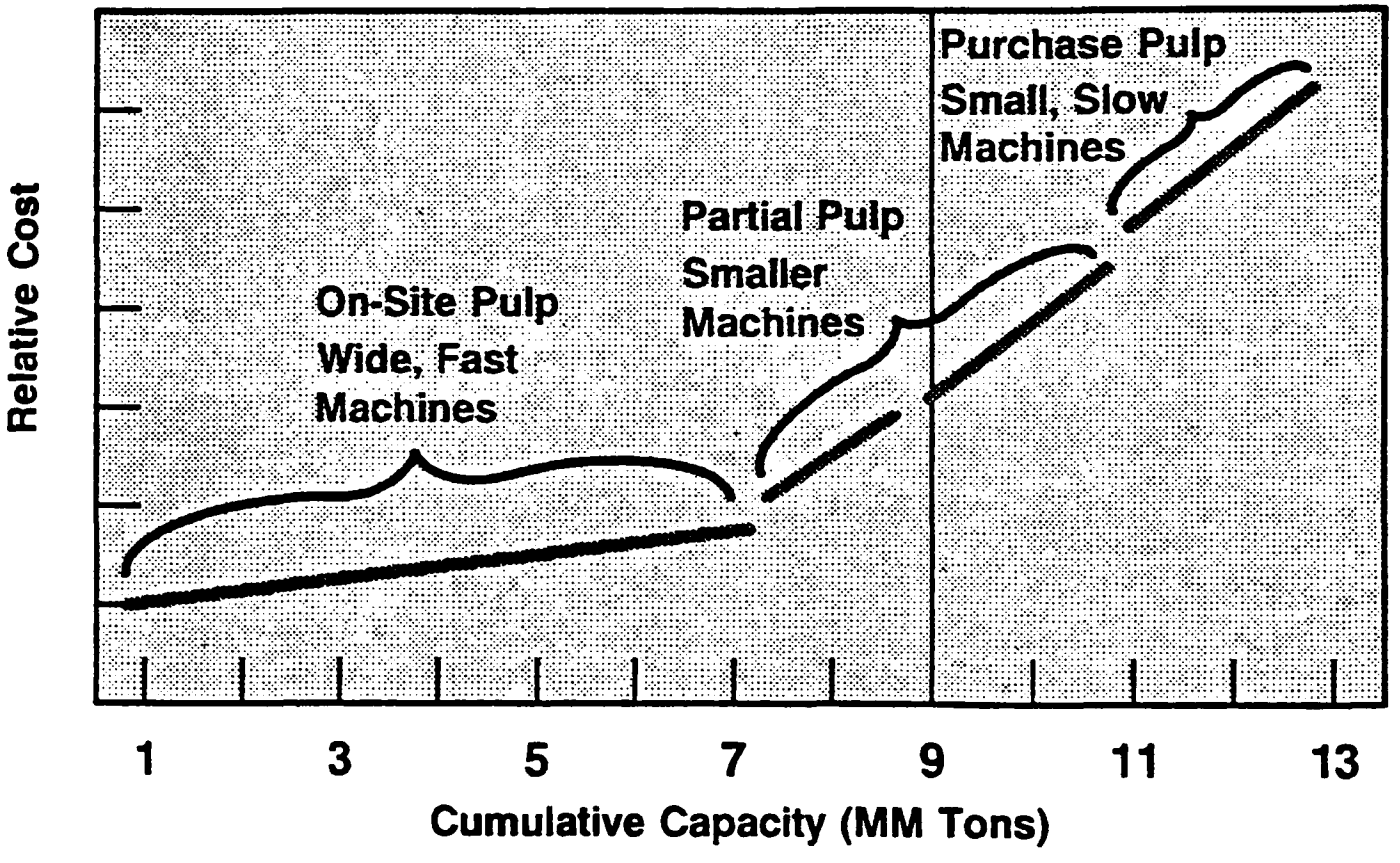

Figure 1.—Production costs for uncoated free sheet.

A line has been placed through the cost curve in Figure 1. Lower cost paper manufacturers producing high volume papers, such as envelope, are located to the left of the line while higher cost producers manufacturing specialty and premium papers are located to the right. The approximate average annual production of the paper machines in the lower cost facilities approaches 100,000 tons. The average production of the machines to the right of the line is only 33,000 tons.

This demarcation line for high volume paper producers will continue to move to the left as newer, wider, faster paper machines are constructed. Today's newest machines are capable of producing more than 350,000 tons of paper annually. Partially and nonintegrated paper producers have little choice but to continue the transition from the production of high volume papers to low volume, high priced premium or specialty papers or go out of business.

The facilities at the highest end of the cost curve generally possess small paper machines using purchased pulp. The costs to make paper are high, but the price for these products provides the returns necessary to operate the facilities. These mills also purchase expensive deinked pulp, and recycled papers have found a solid home in this niche.

Premium papers are purchased when the impression of the message is as important as the printed information. Approximately 40 percent of the high priced cover and text papers sold today are made using recycled fiber. Only 10 percent of this paper contained recycled fiber as recently as 1990. However, cover and text papers accounted for only 3.7 percent of the uncoated free sheet shipped in 1991, and the growth of the market should only continue to roughly track the gross domestic product (GDP). The high cost to manufacture paper at these facilities keeps them out of the high volume envelope market whether or not their products contain recycled fiber.

As stated earlier, recycled papers cost more to produce than high volume virgin papers. Significant processing costs for sorting, cleaning, deinking, and bleaching must be added to the cost of any raw material used to isolate fiber for the manufacture of recycled papers. The cost of the raw material will determine whether a paper grade can be manufactured profitably at competitive market prices. The average price for waste newsprint in the United States in December 1991 was $12.50 per ton, while selected deinkable free sheet grade prices varied from $138.13 per ton to $190.63 per ton for white ledger and laser-free computer print-out paper, respectively (Miller Freeman, Inc. 1991).

The community infrastructure to collect and sort newsprint has been in place for years. The low cost of this readily available raw material provides an opportunity for papermaking facilities with deinking plants to compete in niche markets where the lower brightness of groundwood-containing products is acceptable. Unfortunately, low paper brightness from groundwood papers has not been acceptable for envelope end-users. In fact, groundwood and its cousins, the "alphabet pulps" — chemithermomechanical pulp (CTMP) and bleached chemithermomechanical pulp (BCTMP) — are not allowed in high-volume envelope papers. The high speed optical readers used today by the U.S. Postal Service require high contracts between paper and print to assure efficient mail sorting.

Once again, the market price of free sheet high-volume envelope papers reflects the fact that they are manufactured on predominantly low-cost, high-volume paper machines in facilities fully integrated with on-site pulp mills. Consequently, nonintegrated facilities with deinking plants may produce envelope papers, but do not offer a long-term supply option.

Fiber Reclamation

A portion of the fiber that paper mills purchase today is supplied by the envelope industry. According to EMAA data, only 72 percent of the paper for envelope production ends up in envelopes. The remaining amount, approximately 25 million tons, ends up as a process by-product. Nearly all of this paper is reclaimed. The unprinted trimmings and cuttings are carefully collected and resold as a premium grade of pulp substitute. Printed and mixed waste is also collected and sold as a raw material to the existing recycled pulp mills.

The composition of the envelope paper by-product stream reflects the business and product mix of the envelope manufacturer. Mail-Well's process by-product stream is composed of approximately 70 percent unprinted, 18 percent printed, 8 percent white, colors, and printed combined, and 3 percent mixed papers. The mixed component contains a variety of small volume items including rejected envelopes with glue and windows. This waste is sold for reuse or reclamation at a market determined price, depending on color and quality.

Collecting and selling unused paper makes good business sense to the envelope industry. The sale of unused fiber is an important source of revenue for envelope producers. This does not

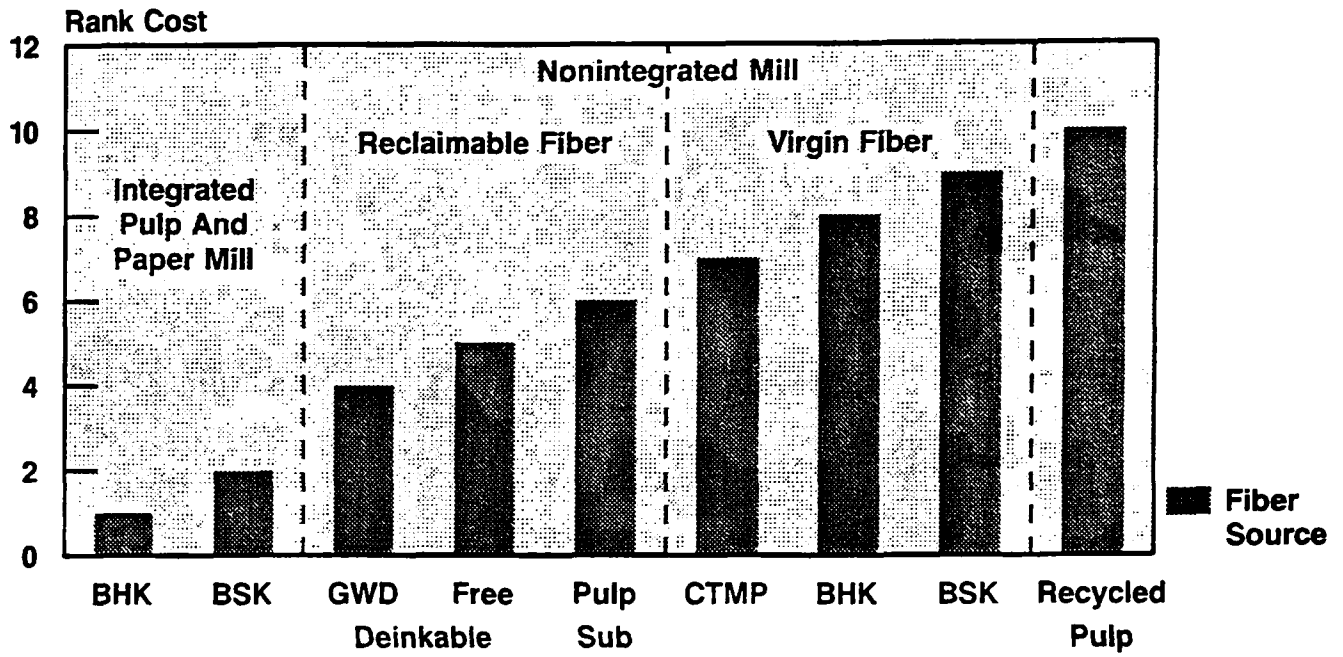

Figure 2.—Ranked costs of fiber to a paper mill.

mean that the by-product is more valuable than the purchased paper; envelopes generate the profit. However, envelope manufacture is a highly competitive business in which cost containment is almost as important as product price. Reclaiming and selling leftover process paper provides valuable revenue to offset the inherent design losses from envelope preparation. This valuable fiber has not and should never see a landfill.

Figure 2 displays a rank ordering of the cost of fiber to a paper machine from various sources. Although the price of envelope cuttings is significantly greater than the cost of on-site pulp to a paper machine, hard-whites pulp sub can be purchased by partially integrated and nonintegrated mills for a lower price than market pulp. Unused envelope paper is an appropriate alternative to purchased pulp for some higher cost mills producing higher priced paper products.

The availability of envelope cuttings will not improve for nonintegrated paper producers for several reasons. First, growth in envelope production is expected to be modest, roughly equal to the GDP. Envelope paper use, as measured by American Paper Institute (1992a), increased at a compound annual rate of only 1.6 percent between 1986 and 1991, almost matching the GDP which grew at a rate of 1.9 percent. Second, as stated earlier, most of the paper by-product from envelope manufacturing is currently being recovered. Third, producing envelopes is a better source of income than selling paper cuttings.

Minimizing process waste is a high priority among all envelope manufacturers. It should be kept in mind that envelope manufacturing waste seldom finds its way back to envelope paper. Envelope cuttings are used by higher cost, partially integrated and nonintegrated paper mills. On-site pulp manufacture is the lowest cost approach for obtaining fiber. Specifying a waste component for reuse in envelope papers will only add cost to the highly competitive raw material.

Concerns About Postconsumer Content

Envelope manufacturers are dedicated to improving the efficiencies of their operations through reducing the amount of paper cuttings and by improving the up-time of the converting equipment. The recycled papers available today that contain postconsumer waste tend to display highly variable properties, for example, appearance, strength, and performance. When paper strength is low, the production rate of envelope equipment must be reduced, which raises manufacturing costs. Frequent breaks from poor paper properties increase waste.

Some recycled envelope papers can be managed to run reasonably well on envelope converting equipment. The cost of set up time can be expected to go down as experience running these papers increases. However, it is difficult to expect that papers containing high levels of post consumer fiber will ever perform as well as virgin papers.

Postconsumer waste tends to be laden with contaminants. Some of these contaminants, even after deinking, end up in the recycled paper where they act as defects. Defects are not only aesthetically undesirable; they also degrade paper performance on high speed envelope converting equipment.

Envelope production is a highly competitive industry where manufacturing efficiency dictates profitability. Today's envelope paper by-product is considered a premium pulp substitute. Poor performing paper would affect envelope manufacturers negatively on two fronts. Low strength and contamination could reduce hard-won manufacturing efficiencies and productivity as well as replace a premium value by-product with a less desirable, lower valued contaminated waste.

Fiber to Energy

In cases where the collection of fiber is not possible, such as on envelopes sent to residences, converting fiber to energy makes more sense than the costly activities to reclaim fiber for reuse in paper. In this way, the fiber is in fact reused — but to make energy rather than paper — and the objective of reducing the volume of paper products going to landfills is satisfied. The achievement of the 40 percent recovered paper goal in 1995 still leaves 50 million tons of discarded paper unused. Converting this noneconomically reclaimable fiber to energy is an option that makes economic sense since energy is a valuable commodity. There are more than 6,000 coal-fired boilers in operation with the ability to use 900 million tons of coal. Pelletized fuel would displace 5 percent of this capacity with a cleaner burning substitute.

Georgia-Pacific has a fiber-to-energy pilot program at its Crossett, Arkansas, operation. Nonreclaimable waste paper from Ashley County, Arkansas, will be pelletized and sold as supplemental fuel to the Georgia-Pacific mill in Crossett. This project should reduce the waste to the Ashley County landfill by 65 percent. Cost-effective solutions to landfills for nonreclaimable fiber are appearing.

Alternatively Bleached Fiber

Our customers have not requested envelopes manufactured from so-called totally chlorine-free paper. Of course, we will work to satisfy requests, if they appear, as we have for requests to supply envelopes made from recycled paper. However, quality paper must be available at competitive prices. We expect to experience greater difficulties in procuring chlorine-free envelope papers than we experienced in procuring recycled papers. We have learned from our recycling activities that two key requirements must be met to satisfy any new customer requests.

Totally Chlorine-free Papers

First, totally chlorine-free papers must be available at prices competitive with existing envelope papers. Customers willing to pay a premium for chlorine-free products will most likely be the exception rather than the rule — as they are for recycled papers.

Essentially, no price premium has been realized for envelopes incorporating expensive recycled fiber. Situations in which a price premium has been realized that reflects the higher costs of the recycled paper are expected to be evermore infrequent in the future. Similarly, we expect price parity with existing envelope papers to be a requirement for the long-term viability of any envelopes sold to high volume, highly competitive end users. If a niche for chlorine-free envelope papers evolves, it is likely to be in markets currently satisfied by existing high-priced premium products such as writing grades and cover and text papers.

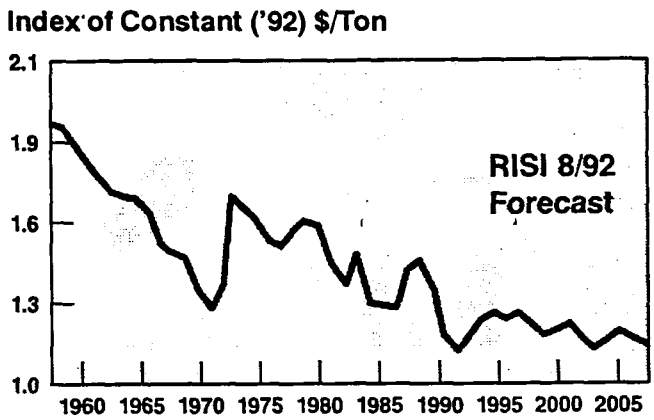

Figure 3.—Relative industry prices for uncoated free sheet as compiled by Resource Information Systems, Inc., Bedford Massachusetts.

Figure 3 presents an index of the historical and projected price of uncoated free sheet paper between 1959 and the year 2005 in relative constant 1992 dollars. As was discussed in the situation analysis of recycled papers, the price for high volume papers used to produce envelopes reflects the lower competitive costs of fully integrated modern paper-making facilities. As a result, the constant dollar price of uncoated free sheet papers has steadily declined and is projected to continue to decline. Any increase in the cost to produce that fiber will jeopardize the competitive position of the U.S. paper industry in the world market. With today's technology, the elimination of chlorine

from the bleaching process for kraft pulps is unnecessary, since emission targets are being satisfied. In addition, these changes are prohibitively expensive.

Second, envelope stocks produced from chlorine-free pulps must meet the quality and performance standards of today's papers. Most of the current chlorine-free pulp is produced in sulfite mills. We do not believe that these pulps meet the above criteria because the sulfite process is generally more costly to operate than kraft mills at modern facilities, and the suitability of the fiber produced for high performance envelope grades is questionable.

Chlorine-free Fiber Source

Sulfite pulp displays lower strength than pulp produced using the kraft process. Long fiber is the primary source for strength in envelope papers. The sulfite process is seldom used in the United States for producing the softwood pulp that is used in performance papers such as envelope. In fact, the kraft pulping process was developed to take advantage of the strength properties of long fiber. Envelope papers must be strong to assure cost-effective operating efficiencies at envelope converting facilities. Reducing the paper's strength would require a corresponding increase in the weight of the envelope paper to assure good performance of the converting equipment, a move that is counter to source reduction strategy.

Sources of sulfite pulp are limited and represent only 4.7 percent of bleached pulp production. In the United States, available bleached pulp made from the sulfite process has decreased at a compound annual rate of 3.9 percent between 1980 and 1990. At the same time, an additional bleached kraft capacity of 8.6 million tons has been introduced (Am. Pap. Institute, 1992c). A few sulfite mills are still producing printing and writing papers at older, higher cost facilities, particularly in Europe, and especially Germany. Once again, these operations tend to produce higher priced grades to avoid competing with the lower cost structure of the newer U.S. world-class facilities.

Bleached pulp production costs will increase if the use of a totally nonchlorine bleaching process is imposed. Still, nonchlorine bleaching may be a less expensive alternative to expending the significant capital dollars required to replace an existing sulfite mill with a new kraft mill. Again, these older sulfite pulp mills are already more costly to operate than Kraft mills. "Chlorine free" technology will further increase sulfite pulping costs..

On-site pulp production will also remain a lower cost alternative than purchasing market pulp. Higher cost, partially and nonintegrated papermaking facilities can purchase any available market totally chlorine free pulp to produce paper. Higher cost mills are not viable long-term options for envelope production regardless of the bleaching technology.

Quality is a paramount concern for performance paper grades such as envelope. The intensity of the bleaching process is guided by the acceptable trade-offs in strength and brightness. Strength is critical for acceptable product performance, while brightness is customer driven. We understand that today's proposed TCF approaches severely reduce strength as market brightness is sought. Because strength cannot be sacrificed, we are concerned that a decline in initial pulp brightness will result from the imposition of chlorine-free bleaching. We know that customers will not accept lower quality whether the product is envelope or premium grades. Costly chemical brighteners may be needed to maintain competitive paper quality.

Summary of Alternatives to Chlorine Bleaching

It will be difficult to find high quality chlorine-free paper that is competitive for use in envelopes. Some markets may evolve for chlorine-free paper, but these niches will be in markets where volume is relatively small and growth is limited. Only the manufacture of higher priced products can provide the returns required to offset the higher costs of production. We must keep in mind that today's bleaching processes continue to meet and exceed both product performance and pollution guidelines as well as offer the lowest cost approach to providing safe paper products.

The Ink Story

Envelopes are used to contain and protect documents for delivery through the mail as well as to present information and a message. This information can be as mundane as an address or as unique as an advertising statement composed of multicolor, high-coverage graphics. Quality printing is an important and necessary component of envelope production.

Changing Inks

According to EMAA data, approximately 65 percent of all envelopes are printed using the flexographic process in which a flexible plate containing the raised image transfers ink directly to the envelope paper. The balance is printed using the offset process. Envelope printing has enjoyed a

dramatic change since 1980 when 70 percent of the printing was accomplished using solvent-based inks. The flexographic process is almost entirely 100 percent water-based.

The industry will continue to work in partnership with its ink suppliers to promote the ongoing development and further implementation of water- and vegetable-based ink resins in offset printing, which will further reduce the use of solvents in the printing environment and in the waste streams.

Source Reduction

One of the most exciting developments in the envelope industry can be seen in the pilot trials at Mail-Well for on-site formulation of aqueous flexographic ink colors. Flexs inks are a close cousin to latex paints. Colors can be prepared on an "as needed" basis, like paints, to complete a single job. Thus, the waste and possible disposal issues for unused ink colors can be avoided.

Reclamation

The reclamation of waste inks is another exciting development. Unused ink is being recycled at several Mail-Well locations. Excess ink colors are collected, mixed and returned to the original ink supplier for reformulation. The ink vendor adjusts the mixture to produce a recycled black ink that is sold back to Mail-Well for reuse. This successful recycling project prevents pollution and reduces operating costs. Lower costs assure that ink reclamation will be a long-term management and technological approach to pollution prevention.

Conclusions

The envelope industry is proud of its obvious successes in pollution prevention and waste avoidance. The activities discussed here and any additional efforts are the consequence of an environmental partnership between manufacturers and suppliers. The results are long-term solutions because they make economic sense. Thus, for example, envelope waste is reclaimed because it makes economic sense.

Recycling for paper production also makes economic sense when the fiber is a lower cost alternative to other fiber sources. The by-product paper of envelope production is almost completely used today at partially or nonintegrated papermaking facilities producing higher priced products. Economics must be allowed to dictate the appropriate end-use for fiber. Cost-competitive, high-volume performance grades such as envelope paper do not provide the most effective long-term area for use of postconsumer fiber. Postconsumer fiber may be more effectively used in papers that have less demanding requirements for aesthetics than envelopes. Converting nonreclaimable fiber to energy makes economic sense.

Chlorine-free envelope papers are not in demand. Today, the sulfite process appears to be the most appropriate application of nonchlorine bleaching technology. However, these processes either reduce the strength of paper-making fiber or provide lower brightness paper. Kraft pulps will still be required to maintain the demanding performance requirements of envelope papers to avoid increasing the weight of the paper.

Today's kraft bleaching processes continue to meet and exceed pollution guidelines. Legislating bleaching technology does not make economic sense and is not a long-term solution.

The transition of envelope printing to water-based flexography is an example of progress that is long-term because it prevents pollution and lowers manufacturing costs without sacrificing quality. The envelope industry in the United States, along with the pulp and paper industry, will remain world class and cost-competitive as long as sound business decisions continue to guide the introduction of innovations.

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Creating Demand for Environmentally Preferable Paper

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Environmental Impacts of Paper Manufacturing and Consumption

The United States' propensity to use ever larger amounts of paper, especially bright white paper, has two significant environmental impacts. First, pulp and paper manufacturing generates significant air and water pollution. Second, U.S. consumption of paper — 580 pounds per person per year on average — makes discarded paper by far the largest component of municipal solid waste. Pollution prevention technologies exist, however, and will become more profitable industry investments as consumer demand increases for environmentally preferable paper products.

Chlorine Bleaching

Improving manufacturing processes and eliminating chlorine-containing chemicals from the delignification and bleaching of pulp will practically eliminate water pollution, significantly reduce effluent flow and lower chloroform air emissions. Currently, organic waste from bleaching stages that use chlorine-containing chemicals must be discharged because the chloride ion in the wastewater is very corrosive. The long-term goal is for pulp mills to recycle most or all bleach plant effluent to the recovery boiler, thereby obtaining additional fuel value from the recovered organic waste.

Eliminating chlorine compounds from the bleaching process also offers significant reductions in water pollutants such as biological oxygen demand (BOD) and color. The effect of these process changes is most apparent when one compares the effluent from Union Camp's traditional bleaching sequences with that projected for its ozone extended delignification or oxygen extended delignification (OZED) process now in the final stages of installation in Franklin, Virginia. Union Camp's oxygen extended delignification process yields an 85 ISO brightness pulp that uses 75 percent less chlorine dioxide than a bleaching sequence with 100 percent chlorine dioxide substitution. As shown in Table 1, this process also produces 94 percent less BOD and 99.2 percent less color for softwood pine bleached to 82 ISO brightness (McCubbin et al. 1992).

By moving to nonchlorine-compound bleaching processes, pulp mills can eliminate chlorinated organic compounds, a major environmental hazard, from water and air discharges. Most chlorinated organic compounds (with the exception of chlorofluorocarbons) have high levels of biological activity regardless of their therapeutic or harmful effects (Fleming, 1992).

The detrimental effects of persistent chlorinated organic compounds on the health of wildlife and humans have been documented (Great Lakes Sci. Advis. Board, 1991). Although our knowledge of chlorinated organic compounds present in pulp mill effluent is increasing, there is still much to learn. Of the 313 organic compounds identified in a study of pulp mill effluent, 205 are chlorinated organics (McKague et al. 1989). Significant amounts of chlorinated lignins are also discharged. Jokela and Salkinoja-Salonen (1992) have shown that the average molecular weight (M_w) of the chlorinated organics isolated from four bleached kraft mill effluents ranged from 330 to 550. C. Wesen (1988)

Table 1.—Comparison of conventional and chlorine-free bleaching at Union Camp, Franklin, Virginia.

	UNITS	CEDED	OC/D(30)D	OZED
Bleach plant effluent flow	m^3/t pulp	47.0	16.0	14.0
Southern Pine Pulp To 82 ISO Brightness				
TOX in pulp	kg/t pulp	0.28	0.13	0.04
TOX in bleach plant effluent	kg/t pulp	6.5	3.0	0.08**
Chloroform generation	kg/t pulp	0.18	0.008	0.002
BOD in bleach plant effluent	kg/t pulp	16.0	7.0	1.0
Color (APHA chloroplatinate)	kg/t pulp	185.0	42.0	1.5
Breaking length	km	13.8	12.4	12.3
Viscosity		17.0	13.0	11.0
Tear	dm^2	111.0	119.0	124.0
Bleaching chemical cost*	$US/t	50.0	33.0	17.0
Mixed Southern Hardwoods to 82 ISO Brightness				
TOX in pulp	kg/t pulp	0.2	0.12	0.03
TOX in bleach plant effluent	kg/t pulp	3.0	2.0	0.06**
Chloroform generation	kg/t pulp	0.18	0.1	0.002
BOD in bleach plant effluent	kg/t pulp	8.0	4.5	1.0
Color (APHA chloroplatinate)	kg/t pulp	55.0	12.0	0.5

*At typical U.S. costs, assuming current dioxin control measures have been implemented.
**Depends on amount of chlorine in chlorine dioxide.
Source: McCubbin Consultants, 1992.

found that 60 percent of the substances recovered from fish and sediment had molecular weights above 300. Highly studied acutely toxic components of mill effluent, such as dehydroabietic acid, most chlorinated phenols, and guaiacols, all have molecular weights below 300. We may also discover new compounds with health effects as serious as dioxin's have been. For example, one review article discusses a chlorinated organic compound that is an extremely potent bacterial mutagen (Holmbom, 1990). Since the mix of chlorinated organics cannot be controlled in the pulp manufacturing process, the International Joint Commission on Great Lakes Water Quality recommends that "industry and other affected parties develop timetables to sunset the use of chlorine and chlorine-containing compounds as industrial feedstocks" (Int. Joint Comm. 1992).

Solid Waste and Recycling

Solid waste is the environmental impact most widely recognized among the general public that results from mass paper consumption. Paper and paper packaging currently comprise about one-third of the 162 million tons of trash disposed in landfills and incinerators in the United States (Franklin Assoc. 1992a). Paper is also the most widely recycled material in municipal solid waste. As we collect more and more paper in curbside and office paper recycling programs, it is critical that we also expand the markets for recovered paper.

Increasing the use of recycled fiber in printing and writing paper products has paramount importance, especially in papers used in office applications, commercial publications, business forms, books, and magazines. Only two producers of recycled printing and writing paper in the United States have the equipment to remove significant quantities of laserjet and photocopy ink from recovered office paper. A handful of additional mills make recycled printing and writing paper using recovered paper that is less contaminated as a raw material. Paper recycling technology in this sector is improving rapidly, but more mills need to install it. Overall, in 1990, 22 million tons of printing and writing paper were consumed in the United States, but only 1.4 million tons of recycled fiber were used as a raw material in printing and writing paper manufacture; the remaining 94 percent was virgin fiber (Franklin Assoc. 1992b).

For other paper products, for example, newsprint, corrugated boxes and recycled folding cartons (such as cereal boxes), the paper industry is already making major investments to add recycling capacity. In 1989, for example, there were nine newsprint mills in North America that consumed old newspapers for some or all of their fiber supply. By 1992, 19 such mills were operating. Recycling capacity had been added to 10 mills that had formerly used only virgin fiber. By 1995, the total will be about 30 (or roughly 40 percent of newsprint mills in operation; old newspapers are also used by mills that make recycled boxboard packaging) (Am. Papermaker, 1992).

Currently, the availability and pricing of recycled printing and writing paper are often not competitive with virgin paper. Although the relatively few mills that produce recycled printing and writing paper often have lower raw material costs

than nonintegrated virgin mills, the recycling mills tend to be smaller and older, and hence have higher overall costs than major virgin producers. Until consumer demand is demonstrated, the largest, most efficient producers of printing and writing paper will remain hesitant to add recycling capacity.

Importance of Consumer Demand for Environmentally Preferable Paper

Change in the capital-intensive paper industry is usually slow and incremental. Traditionally, paper mills have been critical of investments in pollution control technology since such investments usually do not increase mill productivity. The paper industry is also quite competitive, however, and ultimately mills must meet the needs of their customers. Major investments in recycling equipment are now being planned at many paper mills. Technology is also currently available to produce white paper without using chlorine compounds, but mills are generally not moving to install it. This reluctance is caused by a combination of cost, risk aversion, a historical commitment to marketing brighter and whiter paper, and the accurate perception that consumer demand for chlorine-free white paper has yet to develop.

The impact of consumer demand on the paper industry is visible in the production and marketing shifts of individual companies that make paper with recycled content. The major expansion of recycling capacity now underway in the newsprint industry is a result of (1) an increased supply of raw materials due to the growth of community recycling programs and recycling by private waste haulers seeking to avoid rising tipping fees; (2) tne expanded use of flotation deinking technology; and (3) demand for more recycled newsprint by newspaper publishers, who are in turn responding to their readers, state legislation (in California, Connecticut, and Florida), and voluntary agreements between publishers and state officials (in Massachusetts and New York).

In the tissue industry, recycling-based companies that have traditionally served the commercial and institutional market have now introduced products aimed at environmentally conscious households. The Fort Howard Corporation, for example, has introduced the Green Forest™ label, and Green Bay Packaging, Inc., has introduced recycled linerboard products in which the top liner is made with recovered newsprint or office paper (the Ecobrite™ and Ecowhite™ brands, respectively). In order to sell their products in recycled packaging, companies such as Proctor & Gamble, Kodak, and Bristol-Myers Squibb are shifting some of their products into recycled boxboard (the material used to make cereal boxes). This has revived profits and growth in a sector of the paper industry that had otherwise been losing market share for over a decade.

Defining Environmentally Preferable Paper

Manufacturers generally produce what consumers demand. In the paper industry, production methods are changing as consumers become more aware of the environmental issues associated with paper use, particularly recycling. Creating consumer demand for unbleached, reduced brightness, and chlorine-free papers is more difficult since individuals are less aware of the environmental impacts of pulp and paper manufacturing. In comparison, paper procurement officials in business and government, tend to be specialists, and are capable of absorbing a greater amount of information on environmental issues associated with paper production and use.

An initial step in building demand for "environmentally preferable" paper among business consumers is to develop a detailed framework that helps paper purchasers match environmentally preferable papers to specific end uses (e.g., four-color text books, tissue, and cosmetics packaging). As paper users shift demand to environmentally preferable papers, some mills will expand production of existing products and others will develop new products. This change will be an incremental process, requiring cooperation among users, suppliers, and manufacturers. Several types of shifts in paper use can help reduce the environmental impacts of paper production and disposal. Environmentally preferable paper products fall into four major categories. The selection of a given type of paper from these categories will depend largely on the performance requirements of a specific paper product.

Recycled Paper

The oversupply of recovered paper relative to current market demand has put a damper on community and business recycling programs. Recycling markets can be strengthened if businesses increase their use of paper with recycled content. In addition, because recovered office paper, for example, has already been bleached once, producing recycled paper does not require the heavy use of chlorine that bleaching virgin pulp requires. Making paper from recycled fiber substantially reduces energy and water consumption; using

recycled fibers also reduces demand for forest resources and the related conversion of natural forests to monoculture pine plantations.

Unbleached Paper

Many needs, especially in packaging, can be met without the use of bright white paper. For example, the McDonald's Corporation in 1991 switched from white virgin takeout bags to brown, 100 percent recycled bags, and to brown wraps for its Big Mac hamburgers (Capatosto et al. 1991). Kellogg's Eggo™ waffles are packaged in coated unbleached kraft paperboard, a strong, high-quality product that is coated on one side to allow for high quality graphics. This product is a viable alternative to white virgin bleached paperboard (e.g., a doughnut box). A number of office products such as file folders and large envelopes could be made from unbleached or semibleached paper. Of the nearly 26 million tons of bleached paper and paperboard produced annually in the United States, we estimate that roughly 8 million tons are used in applications, primarily packaging, in which whiteness and functionality are not strictly related.

High-yield Mechanical and Sulfite Papers

Because mechanical pulps are bleached with hydrogen peroxide or sodium hydrosulfite instead of chlorine, they are not associated with the generation of chlorinated organic compounds. The same is true of high-yield sulfite pulps. Sulfite pulping produces a creamy colored pulp without bleaching, and a white pulp when bleached with hydrogen peroxide. While not quite as strong or as bright as bleached kraft pulp, paper made from these pulps can be used for a number of applications, such as business forms. The McDonald's Corporation is testing a chlorine-free sulfite paper for its small french-fry bags.

Groundwood, chemithermomechanical pulps (CTMP), bleached CTMP, and high yield sulfite pulps should also be considered because they use trees more efficiently. Yields of these processes range from above 92 percent for groundwood to 75 percent for high yield sulfite, compared to yields for kraft pulp of 45 to 55 percent (McGovern, 1985).

Chlorine-free Bleached Kraft Paper

Several new technologies are available that use oxygen-based compounds in place of chlorine to remove lignin and whiten paper fibers to produce a strong, high-quality pulp. Newly constructed kraft pulp mills in the United States and worldwide are using these technologies because they also cut chemical and pollution control costs. For older mills, retrofits can be expensive, depending on the type of the mill and the products it makes. One factor in determining the economic viability of such retrofits is the brightness required of the pulp, which is usually specified by the consumer. For many types of paper, such as photocopy, ledger, or book paper, brightness can be reduced without impairing the function of the paper. A beige, cream, or ivory paper will be easier on the eyes, and perhaps an aesthetic improvement, but even a barely discernable reduction in brightness may significantly improve the economics of the oxygen-based bleaching systems. Thus, a major opportunity exists to move customer demand toward less bright paper, in turn making it more viable for mills to install nonchlorine bleaching technologies.

Totally chlorine-free (TCF) kraft pulp is currently produced by 12 mills worldwide — 10 in Europe, two in North America (Cox, 1992). These mills use oxygen delignification or extended cooking, or both, with enzymes or other oxygen containing chemicals (ozone, hydrogen peroxide, sodium hydrosulfite) to replace chlorine, chlorine dioxide, and sodium hypochlorite.

Installation of prebleaching stages (oxygen delignification and extended cooking are the most widely used technologies) is a critical step for pulp mills in their move toward the long-term goal of closed recovery systems. Both technologies — a combination is best — reduce the amount of lignin in the prebleached pulp to a low enough level that other nonchlorine-containing chemicals can brighten the pulp to 80 or 85 GE brightness. Reducing the lignin in the pulp before it enters the bleach plant also reduces the amount of chlorine and chlorine dioxide needed to obtain high brightness kraft pulps.

These reductions are significant — oxygen delignification reduces the amount of chlorine used to bleach the pulp by 50 percent. For a plant that produces 1,000 tons of pulp per day, oxygen delignification and 70 percent chlorine dioxide substitution reduces elemental chlorine requirements from 42 tons per day to 6.4 tons per day, combined with 5.7 tons per day of chlorine dioxide (Bettis, 1991).

The elimination of elemental chlorine and sodium hypochlorite is also important since studies show that the chlorination and first extraction stages generate over 90 percent of the chlorinated organics present in bleached kraft mill effluent (Hall et al. 1989). High levels of chlorinated organics are extracted from the first extraction stage because the alkali solution solubilizes many of the compounds that are insoluble in the acidic filtrate from the chlorination stage.

Sodium hypochlorite is a significant concern because it generates large amounts of chloroform, a substance thought to be a probable human carcinogen, as a by-product of the bleaching process. A CEHDED sequence results in releases of 240 to 300 grams per air-dried metric ton of pulp, although the paper industry's National Council for Air and Stream Improvement (NCASI) has reported chloroform emissions exceeding 1,200 grams per air-dried metric ton of pulp (McCubbin et al. 1992). Under the U.S. Environmental Protection Agency's Industrial Toxics Project, companies that emit chloroform to water, land, or air are being encouraged to voluntarily cut those emissions by 50 percent from 1988 baseline levels by the year 1995 (Mies et al. 1992).

For bleached kraft papers, pulping processes that use oxygen delignification and extended cooking with 100 percent chlorine dioxide substitution (no elemental chlorine or sodium hypochlorite) are the next step down a hierarchy of environmental preference. At the top of the hierarchy of environmental preferences is paper made from totally chlorine-free pulp, but four categories exist. They are interchangeable and selection depends on one's specific requirements. The categories are

- unbleached kraft,
- 100 percent recycled kraft,
- hydrogen peroxide and/or sodium hydrosulfite paper (e.g., groundwood, bleached and nonbleached CTMP, and high yield sulfite,), and
- totally chlorine-free kraft.

Following TCF pulp, in order of environmental preference, come bleaching processes that use

- no elemental chlorine or sodium hypochlorite with oxygen delignification and/or extended cooking for kraft pulp,
- high chlorine dioxide substitution with oxygen delignification and/or extended cooking for kraft pulp,
- 100 percent chlorine dioxide substitution (no chlorine or sodium hypochlorite is used [elementally chlorine free]), and
- chlorine with process improvements, such as high chlorine dioxide substitution, elimination of hypochlorite stages, and efficient brownstock washing.

Pulping processes that have oxygen delignification or extended cooking with high chlorine dioxide substitution (the higher the level of substitution, the better) are preferred to processes that use 100 percent chlorine dioxide only. Again, investment in oxygen delignification or extended cooking systems is the first step in the conversion to pulp manufacturing processes with the least environmental impact.

Investment in additional chlorine dioxide capacity will solve the short-term problem of dioxin contamination, but a significant amount of chlorinated organics will still be produced. McCubbin et al. (1992) estimated the adsorbable organic halogen (AOX) level for the eight kraft mills in Ontario with different combinations of pollution prevention technology. With 100 percent chlorine dioxide substitution, AOX levels ranged from 0.35 to 0.75 kg AOX per air-dried metric ton of pulp. The addition of oxygen delignification or extended cooking reduces these levels to 0.24 to 0.60 kg AOX per air-dried ton of pulp. Installation of oxygen delignification and extended cooking with 100 percent chlorine dioxide substitution reduce these levels by an additional 20 percent on average.

If a specific paper use requires pulp bleached with elemental chlorine, a purchaser should work with a mill that minimizes its use. These mills should have made process improvements such as high chlorine dioxide substitution, efficient brown stock washing, and elimination of sodium hypochlorite stages.

Incorporating Environmental Preferences into Paper Purchasing Decisions

Large institutional users of paper make purchasing decisions based on performance, availability, and cost. By adding environmental preferences to this set of criteria — with equivalent weight to other factors — consumers can use demand to reward mills that are making investments and products that improve the environment.

Paper consumers, the environment, and industry can benefit from shifts to environmentally preferable papers. In this section, we present a framework that incorporates environmental preferences into paper specifications. The framework (see Fig. 1) includes criteria from the following three areas:

- performance, cost, and availability;
- environmental preferences; and
- recyclability.

Application of this framework begins with a reevaluation of performance criteria. When identifying performance characteristics, paper users

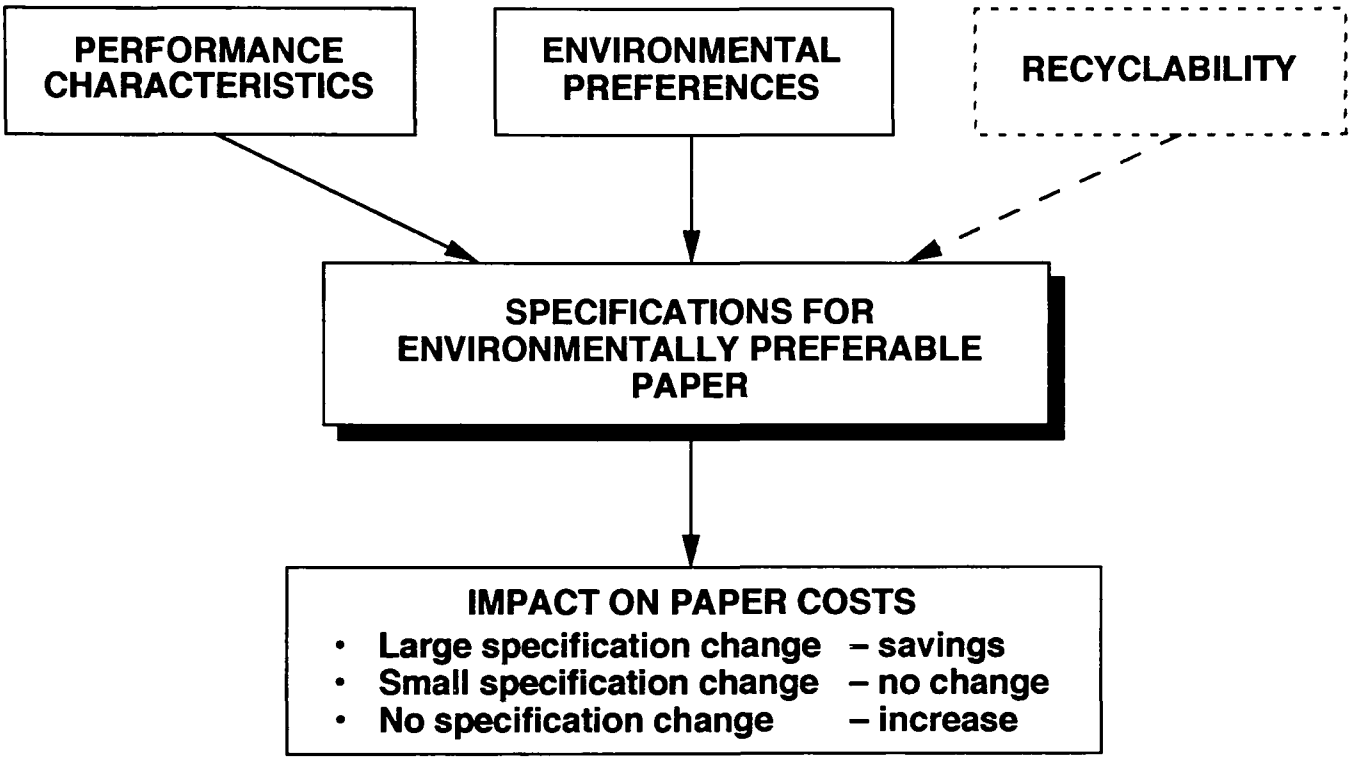

Figure 1.—A framework to incorporate environmental preferences into paper specifications.

should focus on what they actually need the paper to do. Purchasers should consider three major aspects of performance: functionality, brightness, and strength.

Functionality requirements depend on the specific use of the paper product. For four-color textbooks (high quality printing), for example, run ability, low dot gain, low nicking, and linting are important properties of the paper. In the case of brightness, a key question is How bright does the paper really need to be to perform its function? A 5 to 10 point reduction in the brightness of photocopy paper, for example, will not compromise the ability of a person to read printing on the page. Strength requirements vary dramatically for different paper products. For paperboard used for beverage carriers, wet strength and a smooth printing surface are key attributes, while absorbency and softness are important for tissue.

Since the pulp manufacturing process strongly affects brightness and strength, users should evaluate their requirements carefully. Where possible, reducing strength requirements will give paper buyers a wider possible selection of currently available papers made from totally chlorine-free manufacturing processes. An accurate definition of the performance characteristics facilitates the identification of environmentally preferable paper products for a given end use.

With performance characteristics in hand, we can determine which paper grades are actually environmentally preferable for a given use. Paper with recycled content is preferred to virgin paper because use of recycled paper reduces the consumption of virgin materials and builds markets for recovered paperstock.

Unbleached kraft paper is by definition totally chlorine-free paper. One hundred percent recycled paper may be unbleached or bleached with hydrogen peroxide depending on the original brightness of the recycled fiber and the use required of the paper.

Recyclability should also be considered in the selection of environmentally preferable paper. Recyclability depends on three factors:

- the intrinsic qualities of the sheet,
- end use requirements, and
- the local and regional recycling infrastructure.

Coating, for example, can be an intrinsic quality of a sheet. Coated sheet has a high percentage of clay or precipitated calcium carbonate added, which must be separated from the fiber during the pulping process.

Inks, dyes, adhesives, laminates, and other materials also affect recyclability. In some cases the use of significant quantities of groundwood paper (in either virgin or recycled sheet) in office settings can downgrade the commodity value of paper recovered from the office. Setting up stations for

recovering paper of particularly high value, such as impact-printed computer paper, is a partial means of avoiding this problem.

Incorporating environmental specifications may have three impacts on paper costs. In some cases, applying this framework will result in a large specification shift, from bleached folding cartons to unbleached kraft or recycled boxboard, for example, which can lead to significant cost savings. Small specification changes, for example, switching to a totally chlorine-free copy paper with an 80 GE brightness from a virgin sheet with 84 GE brightness, should result in at most a small cost increase. Incorporating environmental preferences, for example, a shift to high brightness (90 GE brightness) and totally chlorine-free printing paper, may increase paper costs. Ideally, the net cost effect of a package of shifts to environmentally preferable paper within a firm will be zero or negative.

Examples

Paper consumers can use this framework to identify the environmentally preferable options for a given end use. Two brief examples of how to identify environmentally preferable paper follow. These examples are simplified and present options for a range of end uses. The actual selection process will require a careful consideration of detailed specifications for a product and how they could change to incorporate environmental preferences.

Folding boxboard cartons are used to package many consumer products ranging from cereal and dog biscuits to cosmetics and pharmaceuticals. Folding boxboard is usually printed with graphics that promote and identify the product. Three types of folding boxboard are available today (see Fig. 2). Clay-coated recycled boxboard has 100 percent recycled content and is coated with clay to provide a smooth white printing surface. The inside of the box is gray, brown, or white, depending on the type of fiber used in the liner. Coated unbleached kraft paperboard is a virgin, unbleached boxboard. It has a clay-coated surface but a brown interior. Solid bleached sulfate paperboard is bleached using chlorine-containing chemicals. It has the smoothest printing surface, and its white interior is preferred by marketers who believe that this packaging promotes an image of hygiene or high quality.

When applying the hierarchy of environmental preferences to a product that could be packaged in any of the materials, we prefer using recycled boxboard because it is unbleached and uses no virgin materials. Coated unbleached kraft would be the second best choice since it is made from unbleached virgin materials. Use of solid bleached sulfate would be the least environmentally preferable choice.

The performance requirements of the end use, however, may require the use of a different material. Coated unbleached kraft boxboard has penetrated the frozen food packaging market, once dominated by solid bleached sulfate, because its superior wet strength results in better performance of the package in freeze/thaw cycles. Cosmetics and pharmaceutical packaging offer an opportunity to switch to an environmentally preferable package

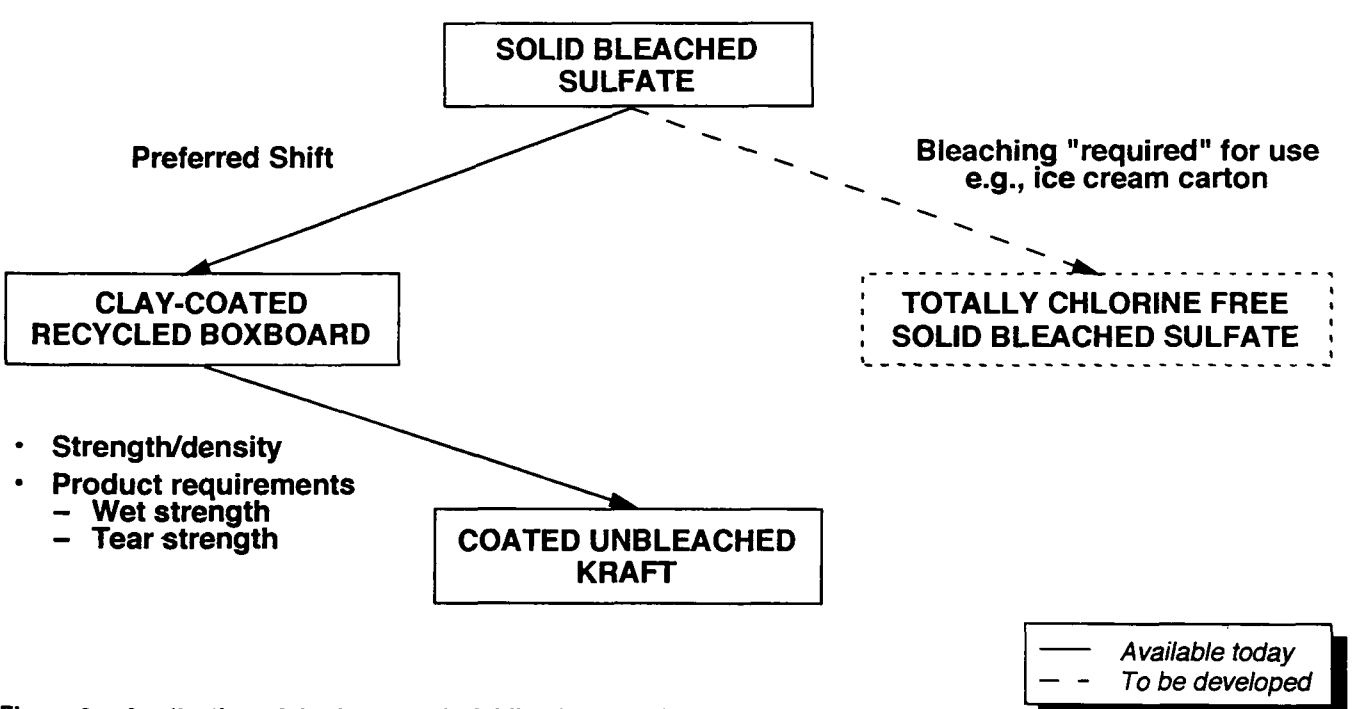

Figure 2.—Application of the framework: folding boxboard.

— they have no functional characteristics that require the solid bleached sulfate packaging.

Direct contact food packaging is another area where solid bleached sulfate packaging currently dominates the market. Both bleached and unbleached kraft boxboard producers can certify to the satisfaction of the U.S. Food and Drug Administration (FDA) that the level of metals and toxic compounds in their raw materials meet the requirements for food contact.

Recycled boxboard producers cannot make this claim because they cannot completely control, and thus guarantee, the content of their raw materials. Recycled boxboard manufacturers, however, are performing the extractive tests required for FDA approval for direct food contact applications. If this packaging must be bleached, the consumer products companies that sell food products can work with solid bleached sulfate producers to create a product that is totally chlorine-free. This packaging will not be available in the short-term, but consumer demand can provide a strong incentive for these boxboard manufacturers to make the necessary investments.

Environmentally preferable options can also replace high brightness printing papers (see Fig. 3). Several possibilities exist for printing jobs that require 85 GE brightness paper. If strength is not a critical issue, printers can use paper that contains BCTMP — for example, the aspen pulp produced by Millar Western's new mill in Meadow Lake, Saskatchewan. Not only is this pulp produced without any chlorine compounds, it produces a strong opaque sheet (McCready, 1992).

Many mills can produce elementally chlorine-free kraft paper using 100 percent chlorine dioxide in the bleaching process. They have not produced much, however, because there has been little demand. Union Camp will also produce elementally chlorine-free paper using oxygen delignification and ozone bleaching. The Franklin, Virginia, mill will produce pulp with comparatively low environmental impact. Mills, including the one in Franklin, Virginia, can produce totally chlorine-free paper, but purchasers and manufacturers will have to work together to see that these products find a market.

Conclusion

To make the market for environmentally preferable papers more efficient, consumers need to understand the importance of and learn how to incorporate environmental preferences into their paper purchasing decisions. Educated consumers will request environmentally preferable papers from their suppliers and will work with their suppliers to obtain them. The Environmental Defense Fund seeks to work with paper users and purchasers to determine specifications for environmentally preferable paper for specific end uses.

The process, however, does not stop with the creation of demand for these products. Buyers, suppliers, and manufacturers must work together to ensure that supply develops to meet the demand for environmentally preferable paper. Creating a market for new paper is an ongoing process — both specifications and products will evolve as mills install new technologies to meet the demand for environmentally preferable products. As mills reap market rewards for making investments in environmental protection, we will see a stream of new products. Thus, creating demand for environmentally preferable products benefits consumers, the environmental community, and the pulp and paper industry.

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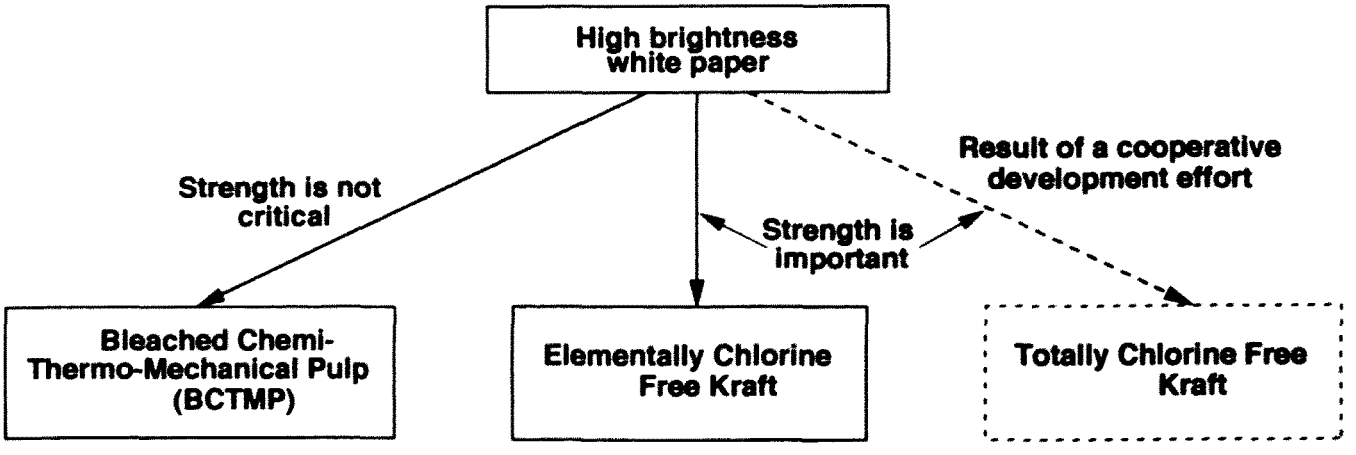

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Panel 1:
Direct Customers

Question and Answer Session

■ **Marquita Hill,** *University of Maine:* I've been listening to discussions about totally chlorine-free paper for three days now and I find myself coming up with a cross between a request and wishful thinking. There are a number of ways, obviously, to produce TCF paper and each has environmental trade-offs that may relate to the subject of pollution prevention. My short-term request is that more precise definitions relative to TCF papers be used; my longer-term desire is that the environmental trade-offs involved in their production be discussed, studied, and better defined vis-à-vis various production methods and vis-à-vis chlorine-bleached paper.

■ **Kathie Emmett,** *State of Washington, Department of Ecology:* I work in procurement programs. I also work with a western states' contracting alliance that represents 17 states who are thinking about collectively purchasing recycled content papers and other environmentally sound papers. State governments are demanding chlorine-free papers; the problem has been availability. We've been looking for chlorine-free papers for two years. It has not been available in the United States, with the possible exception of the mill in New York. But I come from Washington state and I represent states located west of the Mississippi, and we're not willing to go very far from the west coast to buy our paper. We've also been looking for a paper that is bleached without chlorine or only with hypochloride. This paper has not been available either.

I'm beginning to think that requesting chlorine-free paper does not go far enough. I think that by itself this request attempts to satisfy a very complex environmental problem with a very simple solution. The fact is that chlorine is only one of many toxic chemicals used in paper and pulp production. Most procurement people are not chemical engineers, so simply telling us to request chlorine-free paper does not seem to be an adequate or easy solution. I suggest that a better solution would be to look at pollution prevention planning overall and request that more mills become proactive in their programs. They need to develop pollution prevention measures that flow from a comprehensive multimedia approach to their own pulp and paper production.

■ **Peter Radecki,** *Michigan Technological University:* My question is directed primarily at Mr. Church and Ms. Belasco. However, I'm not speaking as a representative of Michigan Tech or anybody else but as a former small business owner with a sales staff, and as a former employee of a major oil company, a role in which I often had salespeople coming in to see me. In both instances, I was often able to influence the products that were purchased by my customers through the educational process that occurs between a potential customer and a trusted salesperson. We've heard a great deal today and throughout this conference with regard to the notion that the supplier or mill will sell what a customer demands. But I think that the educational process is probably the key point in determining how a market is distributed and the types of products that enter it. If I'm an end-user, for example, I may think that I want a certain product. The first thing I'm going to do is get on the phone and call my sales rep, and say, "How about such and such a product; what's the deal on how that product, or process, is viewed within your organization?" My business was in structural steel fabrication, so it's a completely different ball game. But I'm curious to know if that same type of rule applies in the pulp and paper industry. Are you — or

can you — work proactively at pollution prevention through your sales and marketing?

■ **John Church**, *The Cincinnati Cordage and Paper Company*: Thanks for the question, I think. I really do appreciate the opportunity to respond, and I'd like to take the liberty of making an observation. We all came to this meeting with different expectations and from our own personal or business perspectives. I've heard a couple of times now — and this idea is going to reinforce my response to your question — that the perception in the marketplace, either by customers or by media, is that there's a responsibility for organizations and for all of us to educate the customers.

It has also been said that we are not here to debate or to ask why but to discuss how. I find that interesting and fascinating. Again, because we all come here with our own expectations and from our own hill, so to speak, we're standing on our own hill. From our hill, we're the good guys, because we'll do whatever our customers want and whatever our suppliers want. We're the conduit. But I think your question is very pertinent and I don't think I have an answer that you'll like because I don't have one that I like. I do think that we, as an industry, the paper industry — and I'm talking about both the manufacturers and the distributors — are lax in obtaining and at least disseminating information. As my distinguished colleague Don Monefeldt pleaded at the end of his presentation, we must have more accurate data. All of us, manufacturers and consumers, need more and better data.

As a consumer, when I go to the store and buy a recycled product, I'm doing it primarily because it satisfies my personal need. It's an emotional decision, and I don't know when I buy it whether or not I'm really doing something good for the environment. I feel that I am, and that's the way most of us buy things. It's all a matter of perception and we've heard that word before. Perception is everything; perception is reality. But that being true, we do have a responsibility to understand the issues and to disseminate information in the marketplace so that people like me and companies like mine can have the right data and information.

Frankly, we do a lot with recycled paper. We have seminars. We bring manufacturers and other people in to talk about the value and benefits of recycled paper. There are hundreds of misconceptions about the quality, price, performance, and availability of recycled paper. In fact, it's becoming more and more available, more and more competitive, and better and better in quality. And the recycling process is also improving. I suspect something similar may happen with TCF papers. We have become very proactive and have developed some private branded and recycled papers that were the first of their kind in the marketplace. When it comes to recycling, we've educated our sales force, had meetings, and had Pat Dollar on the agenda — she's going to be here later. When she was working for another company, she came in and spoke to us on the advantages and benefits of their recycled papers.

But I have to admit that we're behind the curve on chlorine. And frankly, I would like to know more about the chlorine problem myself before we develop a program in our company to educate the marketplace. And we're talking education now, we're not talking marketing or everyone coming from his or her own needs and developing the data that's available into a marketing program. I don't think that's ethically right. I think we have to look at both sides of the question. We have to get as much empirical data as possible and determine whether the product is right or not, necessary or not, to the best of our ability. Then we can be proactive in the marketplace. Did I answer the question, I'm not sure?

■ **Barbara Belasco**, *General Services Administration:* I can tell you want some answers or guidance from the Federal government. First, I'm almost repeating what John has said. In recycled products, there is a law, the RCRA, that mandates the Federal Government to buy recycled products with as much postconsumer content as possible. And GAO has been actively doing that. We promote it, we advertise it, we have internal magazines that go out to all Federal agencies every month or every other month and every single magazine has an article about recycled copier paper or some other recycled item that we're promoting and encouraging the agencies to buy. Sometimes we run special price sales to the agencies, lowering the price of the recycled product to encourage clients to use it. Only so will they understand that the quality and the performance of these products are no different from regular virgin products.

Our quality inspectors go all over the country. First, they go to mills before the shipments are made; then, if any customer complains about a product, the quality inspector goes on site to the client, reviews the complaint, and writes a report on what they saw and found. We also test the product in the testing laboratory in San Francisco and keep a running account of quality problems. So far, very few of them have been justified. Most problems have been in the machine or its conditioning; — either the paper dried out or the paper was too wet or otherwise misused.

So we're tracking quality. We also promote all the successes that we've had with recycled products. We have a recycled products guide, a special catalog that all the agencies have so that when they want to buy something they can look there first to see if they can use a recycled product. We're very enthusiastic about recycling.

We don't do this at all with chlorine-free paper. Here, we can't take a position pro or con. We've been flooded with information from both sides saying that TCF is bad, that TCF is good. We have this information, but we're a procuring agency. We depend on the EPA to look at the data and to review it technically. They're still working in the laboratory on this issue, so they haven't come up with an answer yet on which way to go. That is why we aren't advertising chlorine-free papers. However, we're getting requests from customers all over the United States for nonchlorine bleached paper. They're coming in without any prompting on our part.

So that's where we are. So far, nonchlorine bleached paper is a new product, and we haven't reached any decision about its worth. But if a customer wants it, we will get it. We're industrially funded, which means that our funds come from sales to the agencies. We're just like a business. If a customer wants something, it's to our benefit to get it for them.

The unbleached napkins, towels, and tissue products that we now have we found in response to congressional hearings. We were asked to make this move; it did not come from customer requests. These products are just sitting in our warehouse. No one ever asks for them. Therefore we have been doing active marketing in this respect and trying to promote the unbleached products. In this case customers have to change their perceptions to realize that a brown napkin is just as a good as a white napkin. That's where our advertising efforts are going right now.

■ **David Bailey,** *Environmental Defense Fund:* Most of my questions and concerns were just addressed. I applaud the remarks of Mr. Church. I think he is right on target and I also applaud the Xerox Corporation. Your conclusions based on your independent research on the dioxin issue may not agree with those of the Environmental Defense Fund or my own. But that's not important. The fact that your companies have engaged in making your own assessment is critically important in determining what the public perception will be.

I think that many potential direct customers are likely to come to you rather than rely on comments from environmental organizations or the paper industry. The responsibility you show and your willingness to be a player is admirable, and I encourage you to continue to do that. I also believe that when EPA finishes its dioxin reassessment, it will provide everyone with scientifically developed data by some of the best people in the world. I would encourage you to reevaluate your position on dioxin when that assessment is available.

■ **Steve Levitas,** *Environmental Defense Fund:* I have a question for Ms. Belasco and Mr. Cousin. Ms. Belasco, you talked about consumer awareness about unbleached towels and other tissue products in terms of the lack of relationship between whiteness or brightness and functionality. To what extent is the Federal government looking at specification changes dealing with brightness in the printing and writing grades? I just got a letter from my Congressman, actually a newsletter, in a brilliantly white envelope. The materials on the table here also have a fairly high brightness level. As there's really no functional reason to continue this cult of whiteness, I wonder what the Federal government is doing in that regard. Similarly, in the private sector, I didn't hear any discussion about reduced brightness specifications for envelopes. It seems to me that this issue is a tremendously productive, constructive, and promising way to help reduce environmental impacts and chemical use and to do that in a way that has economic advantage for the producers.

■ **Barbara Belasco:** We have many envelopes now that are completely unbleached; we also use white envelopes. If a customer requests an envelope of a lower brightness, or if a customer requests a totally chlorine-free envelope that we discover we can only obtain with a lower brightness, then if those customers are willing to accept the lower brightness, we will certainly change the specification.

■ **Steve Levitas:** Well, but I'm suggesting that we need more leadership from GSA — from the top — on these issues rather than relying on the customers. You need to do the same thing in the printing and writing grades that you're already doing in a very commendable way in tissues. So I hope that bringing the whiteness or brightness down will be included in some of your revisions of the specifications.

■ **Barbara Belasco:** Yes, as part of the solicitation that we're going after now, we may have to consider doing something like that.

■ **Steve Levitas:** That would be great.

■ **Rebecca Todd,** *Sierra Club Legal Defense Fund:* I have a few questions. First, Mr. Cousin, I think that

if your perspective in this debate is that chlorine-free products are not a viable solution, then it should come as no surprise if your customers do not request chlorine-free products. Second, I would like a clarification from you as to why you think chlorine-free products are not a viable solution?

■ **Michael Cousin,** *Georgia-Pacific Corporation*: I'm speaking in terms of availability. As I said, we looked at the question, where, if our customers requested it, we would get the paper. We looked at the structure of the industry, and the only chlorine-free option seems to be in sulfite. Sulfite really isn't an option in the United States for commodity papers and envelope papers because a sufficient amount can't be found. The second possibility or source was the conversion of the kraft process to eliminate all chlorine products, but we saw that this source adds cost. The cost structure that we're dealing with, in today's terms, does not justify TCF products as a viable option for us — even to satisfy a demand should it arise.

■ **Rebecca Todd:** Then haven't you also precluded your customers from requesting chlorine-free paper from you even if they are willing to pay the additional costs? You're saying that it's not a viable solution because we say it's not. But if you were willing, because of customer demand, to look at chlorine-free options, then perforce, it would become an option.

I have a question also for Ms. Belasco. I believe you mentioned that you were thinking of adding other chlorine-free products to your lists and I'm curious to learn what other chlorine-free products you have considered, and also what the source is of the chlorine-free products that you currently carry.

■ **Barbara Belasco:** We're looking at writing papers. The one solicitation we have made is for copier paper. Now we're looking at some grades of writing papers such as bond writing papers, writing pads, note pads, things like that. We really do not have anything now that's totally chlorine-free. Vendors bid to the government; paper mills do not. The vendors can go to whatever sources they want to get the supplies that they then bid to the government. So I really can't tell you what paper mills will be bidding. We will probably know by the end of September who bid on the first solicitation for chlorine-free paper. Then I could let you know, if you give me your name.

■ **Mark Floegel,** *Greenpeace:* I have a short question for Mr. Cousin. I've heard you say that Georgia-Pacific has decided against chlorine-free technology and they've also decided against sulfite technology. But it's my understanding that in your Bellingham, Washington, mill you make a chlorine-free, sulfite market pulp. Can you comment on that?

■ **Michael Cousin:** I don't have a comment. My talk concerned commodity envelope papers and that's what I'm aware of. Bellingham is a tissue mill.

■ **Mark Floegel:** I believe it's somewhat integrated and somewhat pulp.

■ **Nick Lardieri,** *Scott Paper Company:* After hearing these comments about whiteness and GSA's specifications for toilet tissues, unbleached with no dirt specks, I really wonder where the supposed cult is.

■ **Hillel Gray,** *National Environmental Law Center:* My question is for Mr. Cousin but anyone else may respond. Can you tell me what kind of forecast you used in your cost analysis for increased regulatory costs or potential liability associated with the use of chlorine? How did you factor that into your analysis?

■ **Michael Cousin:** That was a cost . . . you're talking about the relationship for paper machines making uncoated free sheet? That cost analysis?

■ **Hillel Gray:** I'm thinking about your analysis for the year 2000, and whether you expect liability or regulatory costs to increase if you don't move to chlorine-free?

■ **Michael Cousin:** No, as I said, those costs were generated using what it costs today to make a ton of paper on those paper machines. The same approach was used for each machine included in that analysis.

■ **Hillel Gray:** So are you doing any forecasting?

■ **Michael Cousin:** I'm sure we are. I just got the costs, the estimated industry study.

■ **Hillel Gray:** Would you be willing to provide later, in the proceedings of this conference, some information on the company's forecasts on the indirect costs associated with chlorine?

■ **Michael Cousin:** I think I'd have to check with the company. I honestly do not know that information.

■ **John Church:** I think you invited other members of the panel to respond to your question. And my answer is no, we have not done any forecasts associated with the liability of purchasing and selling TCF papers to the year 2000. Or for that matter even to next year. But I think that reinforces my re-

quest and my plea for more empirical data. I don't think we have enough information to make a reasonable and intelligent decision. And as far as trying to forecast the cost of legislation I assume it applies to TCF as well as to using chlorine. For that matter, trying to forecast the cost of any legislation is, if not impossible, extremely difficult.

■ **Neil McCubbin,** *N. McCubbin Consultants, Inc.:* I found Don Monefeldt's comments very interesting, particularly coming from an organization like the Xerox Corporation. You mentioned that your TCF products are currently limited in geographic region to Northern Europe and that they are about 15 percent more expensive. According to my arithmetic, that corresponds to just a little more than the actual cost of making the lignin-like pulp that I presume they're based on, which is all you can buy in TCF today. When Sodra Cell AB starts its ozone system next month and Union Camp's is running (starting up now), then according to my arithmetic, when kraft pulp is reduced, they'll all be about the same price as regular pulp. So if the pulps are about the same price, perhaps TCF xerographic paper will also be at the same price as traditional. What do you think will happen to the market then?

■ **Don Monefeldt,** *Xerox:* Well, we'll find out. I think I have a reading on what you're after. As I indicated, our friends in Europe believe that about half the market will be TCF by the middle of the decade. It's hard for me to imagine that this could occur if it required appreciable price premiums. So it's implicit in their estimate that TCF will become a regular commodity — produced cost-effectively on high-speed equipment. The only way they can get half the market is if their prices are comparable. If I were a salesperson and had access to chlorine-free at no price premium, I'd much rather sell it than deal with the questions that might arise from people who are concerned about the other product.

■ **Med Byrd,** *North Carolina State University:* You talk about creating a demand for totally chlorine-free papers and paper products. It's important to realize that we need to make the consumer aware that these products are an available option. What we really need is to give the consumers complete information and let them make a totally informed choice about the overall effect TCF will have on the environment. And we should do that before we run helter-skelter into creating a huge demand for sulfite mills and abandon the kraft process for a totally chlorine-free process. We don't have the answers yet. There's an incredible amount of research going on, especially at the university level. Research institutions will soon be able to see what the overall effect of this fundamental shift in our industry's going to be. So before we sit here and send the consumer rushing off to meet some new technology, we need to give them the information they need to make an informed, total decision. Let's not meet some short-term, high profile, high publicity goal and throw the baby out with the bathwater. We need to know the complete implications of the changes we're talking about.

■ **Norman Liebergott,** *DuPont Canada, Inc.:* I'm very, very interested in all you have to say about using TCF pulps and recycled paper. But you haven't gone far enough. Because once you have this paper, once you use it, you'll want to recycle it again. And this is where some of the problems come in. This is why we need foresight. Some U.S. secondary fiber mills are still using hypochlorite and hypochlorate. We're trying to get them to use other nonchlorine bleaching chemicals. Now you're giving them another fiber that can be darker and have a little more specks and a bit more kraft in it. Certainly you can use oxygen peroxide and hydrosulfates, but think about it. When you recycle something and you're already using recycled content, you've got to go one step further. So wash things, wash the inks, wash the dyes, wash the encapsulated things, things that are forgotten as you go toward this new product.

■ **Jens Folke,** *European Environmental Research Group:* Those things are beginning to flower, I think. I agree with many of your perspectives. But I am also looking at and coming from a different part of the world. I mean, in North America and Europe, you have 10 percent of the world's population using about two-thirds of the world's pulp and paper products and 70 percent of the world's total energy. My perspective is that if you're willing, you can reduce the absorbable organic halogens down to about 1.5 to 2 ppq, and then it's only speculation that there is any toxicity remaining in that fraction. Now, we know that there is toxicity in unchlorinated compounds, so as I see it, you are wise to continue kraft operations — at least until these ozone plants come into operation. I think you're losing the perspective. I would like to see environmentalists in this part of the world go into energy conservation programs that will really do something for the environment rather than speculate on what will happen if we remove these compounds. If you take the discussion we had yesterday about the principle of precautionary action, what you're saying is that now you have 250,000 people in an organization who believe that this compound or this type of material may be dangerous. And then next year you have another 250,000 saying, okay,

maybe this compound should be removed because maybe it's dangerous. It's like you have to talk to the pope about this. I think we have to go for a deeper perspective, and say, hey, we have developed the ecotoxicological signs on top of all those environmental problems that we discovered during the 70s and now this arch of the last 15-25 years is on its back and we have the tools to deal with it. Otherwise, we are just disregarding knowledge and being willing to pump and burn oil on the speculation that something else may be dangerous. But that's irreversible; once we've burned the oil, we can't put it down in the ground again.

■ **Lauren Blum,** *Environmental Defense Fund:* May I respond, just briefly. I think that what we're really interested in is not to shift from kraft to sulfite, as though that were the way to go forever. We're interested in trying to make consumers aware that there are many different kinds of paper, including papers of reduced brightness. We're trying to make people question whether they really need bright, strong paper for every use. We're not endorsing sulfite, or still less, saying kraft is the only way to go, or that we have to have chlorine-free processes or it won't work. We do realize it will happen over time. So I don't think that is the issue. I think one of the things I've seen as a chemist is that even though science has improved, there's much we don't know and, therefore, reasons to move toward more preventive strategies. On the other hand, energy conservation also matters. Our challenge, and what we have to work on, is balancing all these needs, incorporating them, and including recycling and the need for chlorine-free paper in the equation, so that it's not just one or the other.

■ **James Austin,** *MoDoCell, Inc.:* As most of you are aware, MoDoCell is one of the largest producers of chlorine-free pulp in the world. The largest sulfite mill, yes, is chlorine-free. One of the things we'll be addressing this afternoon is the technology of high-yield pulp, bleached chemical thermomolecular pulp (BCTMP), and Aspen BCTMP in particular. It's a perfect replacement for hardwood kraft. The specification changes that need to be made will be coming out of the EPA group. These changes in the specification standards will begin to allow new technology for high-yield nonchlorine bleached pulps to be used in this country. They are also the biggest hurdles that we have to address in the next couple of years.

The Environment Is Good for Business — A Publishing Company's View

Kit Taylor
Vice President Manufacturing
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New York, New York

As the nation's leading publisher of special-interest, leisure-oriented magazines, Times Mirror Magazines reaches more people actively involved in the outdoors than any other media company. Every month, some 30 million readers across the United States read our nine magazines — *Field & Stream, Golf* Magazine, *Home Mechanix, Outdoor Life, Popular Science, Salt Water Sportsman, Ski* Magazine, *Skiing* Magazine, and *Yachting*. Therefore, Times Mirror Magazines has a responsibility and a unique opportunity to communicate with its readers on key environmental issues.

Two years ago, Times Mirror Magazines translated this commitment into action with the establishment of the Times Mirror Magazines Conservation Council. The Conservation Council's goal is to increase our readers' awareness of important environmental issues and to initiate conservation programs. We use two specific approaches to achieve our goals. We have established an office in Washington, D.C., to work with Capitol Hill, government agencies, and conservation organizations on regulations and legislation affecting natural resources. We also write corporate editorials addressing specific conservation issues and calling on our readers to take action to resolve any problems. These editorials appear quarterly in all our magazines.

To further demonstrate Times Mirror Magazines environmental concerns, we conducted a survey of 1,200 adult Americans with the guidance of the Roper Organization. The poll revealed a surprising sense of awareness among the U.S. public that problems can be solved by balancing environmental protection with economic development. The survey reveals the following important facts about our readers:

- 65 percent disagree with the premise that economic security and well-being have priority over environmental problems;
- 92 percent are optimistic that a good balance between economic progress and environmental protection can be found; and
- 63 percent believe that environmental protection laws and regulations have not gone far enough.

Only 10 percent of our readers believes that regulations have gone too far.

Obviously, our readers have leisure-time passions that are closely linked with outdoor activities.

Paper Purchasing, Processing, and Perceptions

Times Mirror Magazines prints an average of 11.5 million magazines a month. We buy 30,000 tons of paper annually. The basic weight and quality specifications vary within this tonnage depending on its end use:

- 2,200 tons (or 7 percent) of this paper is 70-pound and 90-pound coated cover stock — the brightness specification for this quality of paper is 82 points;
- 24,000 tons (or 80 percent) is lightweight, No. 5, coated groundwood — No. 5 coated groundwood has a brightness specification of 71; and
- 3,800 tons (or 13 percent) of the paper we purchase is 40-pound and 50-pound newsprint stock made of 100 percent recycled magazines.

Times Mirror Magazines made the switch to recycled stock about four years ago, based on environmental and economic reasons. Our readers appreciate the fact that we try to use recycled paper wherever possible.

As the primary paper purchasing agent at Times Mirror Magazines, I make an effort to be as informed as possible on the environmental positions of our suppliers. At the present time, about half of our paper is produced without chlorine bleaching.

The 3,800 tons of recycled newsprint stock referred to earlier is made from 100 percent recycled pulp, which is produced using the flotation process. This method does not require any bleaches in the deinking process, creating a 100 percent chlorine-free product.

One of our large coated-paper suppliers and a major North American mill has cut back from a five-stage bleaching process to three stages. This change reduced effluent dioxin content by 92 percent, demonstrating a significant effort to reduce the impact of chlorine compounds on the environment.

The U.S. paper industry has already invested more than $1 billion over the last three years in improved environmental technologies. The industry has also spent $6.6 billion on pollution control since the 1970s.

The alternatives to chlorine bleaches vary from mill to mill. Most of the mills we buy from believe the demand for elemental chlorine-free paper will increase and satisfy most consumers' environmental expectations. Some mills are making plans to fulfill that demand; others are not prepared to make such a commitment.

Publishing Industry Current and Future Concerns

Today, Times Mirror Magazines' readers have not expressed much anxiety about dioxin and the manufacture of magazine paper. They are still struggling with questions related to recycling. Just as the publishing industry had to learn the terminology relating to recycled paper, now we must learn the vocabulary that relates to dioxin concerns. As our readers become more aware of the effects of dioxin on the environment, the demand for its control will naturally be affected.

Publishers will have to pressure paper suppliers to manufacture paper having as little negative effect on the environment as possible. This requirement may eventually produce totally chlorine-free (TCF) paper. A recent assessment made by National Economic Research Associates concluded that production costs of paper in the United States would increase by approximately $60 per ton as a result of extraordinary capital expenditures to develop TCF processes. These increased costs would obviously be reflected in the prices charged to paper buyers and would, most likely, pass on to readers.

At this particular time in the publishing industry's struggling economic climate, we would have great difficulty meeting any paper cost increases. Paper costs comprise about 35 percent of the total cost of magazine production and any increase on that portion of our costs would be difficult to bear. In many cases, publishers' position with their readers is not strong enough to charge them for additional costs. We need to preserve every reader we have in order to insure our long-term health.

Perhaps Times Mirror Magazines, more than some publishing companies, will have the opportunity to develop a marketing plan that promotes us to our readers as an environmentally conscientious firm that uses TCF paper in its magazine production. I am certain that many readers would be impressed; however, the question that remains is this: Does the publisher have to absorb all the expense, or will readers also be willing to support the environment financially through a higher subscription price?

It is very difficult to survey readers accurately on this subject. If we raise their consciousness further about the issue and then determine that they won't financially support it, we won't have any choice but to incur the expense ourselves — an expense that could be impossible to absorb. It could be very expensive if the issue turns out to interest only a small percentage of our readers.

Nevertheless, to date we have discovered, through the Conservation Council and through our Partnership for Environmental Education with the U.S. Environmental Protection Agency (EPA), that being environmentally aware is smart business. We have indeed positively affected our bottom line with our position on conservation issues that are near and dear to our readers' and advertisers' hearts. However, a huge commitment to increased publication costs would be a very complicated decision.

Times Mirror Magazines is determined to stay informed on all the environmental issues related to publishing. We feel we are making some positive contributions to the environment by our continued research on, and use of, recycled paper; our experiments with vegetable oil inks; our awareness of and influence on the use of chlorine bleaching; and through our Conservation Council efforts. Our company policy is to be environmentally responsible. We believe it is ultimately good business.

Alternatively Bleached Papers and Other Impossibilities

Roger Telschow
President, Ecoprint
Silver Spring, Maryland

I will speak on two interrelated topics this morning. The first topic concerns the demand for alternatively bleached papers; the second, the experience that printers have had working on alternatively bleached papers. I work for a commercial printing company in metropolitan Washington, D.C., called Ecoprint, which, as the name implies, is a very environmentally aware company. I am also something of a conference junkie, so perhaps I can give you a slightly different perspective on alternative technologies.

For years, Ecoprint has used recycled papers. We have also worked with eight or nine different ink manufacturers to find the best, environmentally safe inks. We have also done some research to reduce the volatility of solvents, and we have attempted to eliminate chlorinated hydrocarbons throughout the shop. In general, we have sought ways to prevent pollution and minimize hazardous waste. We use about 350,000 pounds of paper per year, and we do printing for associations, nonprofit organizations, and small publishing companies, among others. Therefore, our papers are primarily coated and uncoated, bond, text, offset grades of paper, and some cover stock.

Current Demands for Alternatively Bleached Paper

Recently, we have seen an increased demand for alternatively bleached papers. This demand has been rising over the years, and, of course, bleaching chemicals have been a concern as far back as I can remember for some people. But I think in the last 24 months, the trend has surged upward significantly. All kinds of people are now asking us if we have a chlorine-free paper, a hydrogen peroxide bleached paper, or an oxygen bleached paper. As awareness of the alternatives to chlorine bleach increase, so will the demand for these alternatively bleached papers.

The price differential — or how much people are willing to pay for these technologies — is difficult for me to say. One of our alternatively bleached sheets is the least expensive sheet that we offer; no one has to pay a premium for it. For some of our other sheets, I think people may pay a premium in the range of 5 to 10 percent. Although I am basing this on a seat-of-the-pants analysis rather than statistics, I would say that this difference is similar to the difference that people are paying for recycled papers. I don't think they would be willing to pay much more at this time, nor is it necessary.

We have imported a German sheet through Canuset Corporation in Baltimore, a firm that imports the Steinbeiss-Hemming Sheet, and we have had some decent market acceptance on that sheet. It is not a super-white sheet, either, but rather gray. It contains 50 to 90 percent postconsumer content, and it is hydrogen peroxide bleached. Essentially, the biggest challenge for us has been to find these sheets that we can take to a market niche. We ask that they be bright, inexpensive, and high in postconsumer content. Right now, as an offset printer, we are probably using 20 percent nonchlorine bleached paper and 40 percent that is bleached using small amounts of sodium hypochlorite but no elemental chlorine or chlorine dioxide. We are also running about 95 percent recycled paper.

Future trends will show a continued increase in nonchlorine bleached papers. I think we are going to see more technologies come on board, perhaps especially in the recycled sector, and more hydrogen peroxide bleaching. So long as we have some groundwood content in the pulp, we really can't rely on chlorine or chlorine dioxide. I think

we will see some real improvements very soon. We have seen improvements even in the last 18 months or so. I am thinking particularly about the Patriot Mill in Boston, which is producing a very marketable product that in some instances has up to 80 percent postconsumer content and the mill is using alternative bleaching. These events will also bring the cost down.

Looking toward the Future

On the observations and suggestions side of things, I think the common goal for many of us is that we want to reduce the impact of papermaking on the environment in all senses. I hear this over and over again, but I also hear of obstacles and costs that lead some to the conclusion, frankly, that these environmentally better technologies are impossible — you just can't do this stuff, or so I hear repeatedly. The caution reminds me of the history we have been through in the last 10 years as a printing company. Ecoprint has been told repeatedly that postconsumer content and alternative bleaching technologies are impossible or uneconomical, or that the alternative is worse for the environment than what we have now.

My observation is that we are too often blinded by the obstacles that face us, When you look at some of the improvements in the printing industry that Ecoprint has experienced, you know that new ideas are possible. We were told, for example, that it was impossible to get recycled papers that were clean, that ran on the presses well, that were available and economical. Today, Ecoprint has paper that meets precisely those specifications. We were also told that it is impossible to run your press without using alcohol. We have been doing that for some time.

Not too long ago, we were warned that it is impossible to get good quality printing without using highly volatile solvents and that we wouldn't be able to find substitutes for the chlorinated hydrocarbons in our cleaning agents. "You won't," they said, "find a substitute for this ozone depleting compound." But we did.

So when we were told at another conference that we would not be able to remove the heavy metal pigments from inks and still have a good quality product, we didn't believe it. We wrote a proposal on the subject to the U.S. Environmental Protection Agency, and they have helped fund our current research in this area. We have made some progress, and I hope we will have a commercially usable product in the next six months.

Ecoprint, I should remind you, is a printing company. We are not a research firm. We are not a pigment or an ink manufacturer. But, we've sought out some help and some subcontractors and some other people in the industry. I'm certainly not here to tell you what heros we are, but to remind you that what we are frequently told is impossible or undoable or uneconomical turns out in a very short time to be the standard of excellence. I think that it is a good idea to keep our minds open to possibilities and accept new projects even if they will only make progress in fits and starts.

We are initially going to have some set-backs and some increase in costs. But I think you are likely to see, as more technologies come on board in the future, that demands will increase, and the right alternatives will be found. Whatever the alternatives are, they are going to reduce dramatically the environmental impact of printing. My appeal would be that we look at change positively and embrace it, rather than see it as an enemy; realize that change in papermaking, printing, chemical technology, or whatever is really what renews us as a graphic arts and papermaking industry.

Remember, too, that papermaking has not been a static process over the years. Needless to say it is only in this century that wood has been paper's primary ingredient. Other ingredients have been everything from rice to cloth to goat skins. One of my favorite examples of how we shouldn't be too resistant to change involves the goats. Imagine printing the Sunday *New York Times* and having to wait while someone rounded up 100,000 goatskins every weekend to print the paper on. Not a pretty sight!

So who is to say what the future will hold? If we can keep our minds open, we can stand at the leading edge of this thing. Maybe. Take a deep breath. We will also need to acknowledge our fear of the unknown, our tendency to say that the devil we know today is better than the devil we don't know yet — to say, "Okay, we are scared of that, but we are going to do it anyway." Make the commitment as an organization, not to wait until your subscribers or members sound the alarm and say, "Hey, why aren't you running environmentally sound paper?"

I am beginning to hear from manufacturers and producers of magazines and other writing papers, who are trying to stay on the leading edge of this. Well, thinking creatively about alternatives is the leading edge, in my opinion. We don't want to get caught with our pants down when Sweden is way ahead of us and has already cleaned-up its sulfite process, for example.

Let's stay at the leading edge and start talking about alternatives now. It will probably take years to accomplish, but it can begin with a few well-

placed phone calls to suppliers from people who buy thousands of tons of paper each year. The buyers are beginning to ask about the papermaking process: "How clean is it? How can we partner with you to clean it up, to make it better?"

This conference is a testament, I would think, to the fact that many of those phone calls have already been made. I see many people here, whereas five years ago, there wouldn't have been so many. I say, "Right on!" I think that we are moving in the right direction — for the sake of the industry and the environment.

Evolving Paper Product Specifications and Market Demand — A Publisher's Viewpoint

Donald W. Hopkins
Vice President and General Manager
Hearst Enterprises Division
The Hearst Corporation
New York, New York

Hearst Enterprises is a major consumer of paper for newspapers, magazines, and books. The grades range from colored uncoated groundwood products of 50 brightness (BRT) to coated No. 2 papers at 85 BRT. In-between are newsprint, at 57 to 60 BRT; directory, at 60 to 64 BRT; uncoated groundwood, at 63 to 70 BRT; uncoated free sheet, at 80 BRT; lightweight coated groundwood No. 5, at 67 to 71 BRT; and coated No. 4, at 75 to 79 BRT, to mention the major products. Newsprint is primarily produced from mechanical pulps bleached with nonchlorine chemicals. All the other products are produced by the sulphate kraft process containing hardwood, softwood, and groundwood pulps.

Most of our suppliers have both chlorine and chlorine dioxide stages in their mill processes. All have either converted the process to eliminate dioxin formation or announced their intention to do so. We base our paper purchases on quality characteristics and economic factors. Long-term availability is essential. Our divisions have not expressed an interest in switching to alternatively bleached paper. Alternatively bleached paper is not currently available in any quantity that we think would meet the quality and cost criteria for paper products produced by Hearst Enterprises.

Customer Description

The newspaper and magazine divisions of The Hearst Corporation sell to advertisers and consumers through subscriptions and newsstands. Books are purchased primarily by consumers. The books and business publishing division publishes the William Morrow line of hardcover books, Avon Books in paperback, and business publications under Motor Professional Books, *Floor Covering Weekly, American Druggist, Diversion Magazine,* Electronic Engineering technical publications, and others.

Hearst is the largest U.S. publisher of monthly consumer magazines with 13 major titles including

Colonial Homes	*Motor Boating & Sailing*
Cosmopolitan	*Popular Mechanics*
Country Living	*Redbook*
Esquire	*Good Housekeeping*
Sports Afield	*Town & Country*
Harper's Bazaar	*Victoria*
House Beautiful	

Hearst is also a major magazine publisher in the United Kingdom. The newspaper division is the 10th-largest publisher in the United States with a daily circulation exceeding 1,000,000 copies in 12 cities. Hearst newspapers include

Houston Chronicle	407,000 Daily/603,000 Sunday
Seattle Post Intelligencer	250,000 Daily/521,000 Sunday
San Antonio Light	155,000 Daily/227,000 Sunday
San Francisco Examiner	131,000 Daily/705,000 Sunday
Albany Times Union	110,000 Daily/107,000 Sunday

Future Action

Hearst relies on the scientific community to continue to monitor the papermaking process to determine the need for fundamental change. Our suppliers have informed us, however, that they are in full compliance with all water, air, and land use regulations in force in the regions in which they operate. In addition, most are modifying their processes to reduce any potentially harmful elements below detectable levels. Based on their reports, I see no need for an alternatively bleached paper.

Printing the IKEA Catalog Entirely on Totally Chlorine-free Paper

Michael J. O'Rourke
Catalog Manager
IKEA U.S., Inc.
Plymouth Meeting, Pennsylvania

Earlier this year, IKEA released its 1993 catalog. As noted in the press release that accompanied its distribution, the catalog is printed on a totally chlorine-free paper (TCF) containing no old-growth forest fibers. The significance of this achievement is clear. The IKEA catalog is one of the largest color printing jobs in the world. It is read by millions of people each year in 25 countries.

To be involved in the environment is part of what IKEA is and flows from its philosophy. Many years ago, IKEA founder Ingvar Kamprad vowed "to create a better everyday life for the majority of people" by offering a wide variety of home furnishing items of good design and function at low prices. IKEA has set out to accomplish this goal in every dimension of its business activities. Ingvar Kamprad, like Sam Walton of Wal-Mart, imbued IKEA with his own personal philosophy about life and doing business.

Established over 40 years ago in Sweden, IKEA is the world's largest home furnishings retailer with 110 stores in 25 countries. Last year, 90 million people visited IKEA stores around the world, generating a total sales turnover of almost U.S. $4 billion.

Caring about the environment is a natural consequence of the IKEA ambition to improve our customers' quality of life. The IKEA spirit of daring to be different created a corporate environmental policy that strives to minimize any possible adverse affects that may result as a consequence of its activities. IKEA is consistently looking at many environmental issues, not just the environmental impact of its catalog.

The IKEA Customer

In the United States, IKEA has 11 stores located in and around such large cities as New York, Los Angeles, Philadelphia, Washington, Baltimore, Pittsburgh, and Houston. IKEA customers in the United States represent a wide demographic profile, as do IKEA customers in 24 other countries. The IKEA customer represents a cross-section of the population in each of the company's retail markets worldwide.

As a result, awareness of environmental issues, specifically the bleaching process and alternatives to bleaching, varies from market to market. California, New York, Canada, and many northern European countries are more environmentally aware than others and have placed more demands on government and industry to deal with environmental issues. On an international scale, public demands for greener products will increase with time as environmental awareness develops and spreads to other countries.

In general, IKEA customers may not be well informed about the bleaching process issue, but a majority react negatively to the word "chlorine" and positively to the term "chlorine-free." IKEA customers in Scandinavia are more knowledgeable than customers in other countries because of a national awareness of the environmental impact of the bleaching process. But corporate philosophy dictates that IKEA should be aware of how its operations affect the environment, and we must be responsible about activities identified as having a negative impact. IKEA strives to meet its own voluntary standards, and since it is an international company, it imposes the strictest local standards on a global basis.

Creating a Totally Chlorine-free Catalog

As noted before, more than 90 million people visited IKEA in 1991. The annual IKEA catalog, produced in more than 15 languages, is the most

important catalyst for attracting customers to its stores. Inter IKEA Systems BV in Holland is responsible for centrally coordinating the total purchase of print capacity and paper for the different versions of the annual IKEA catalog. To meet the total needs for all versions, Inter IKEA purchases 40,000 metric tons of paper annually.

Over a year ago, an Inter IKEA project group met with a paper expert from Greenpeace to develop common environmental goals for the 1993 IKEA catalog. The goals were to prohibit the use of old-growth forest fiber in the paper, to demand a minimum amount of bleaching in the manufacturing process, and to promote catalog recycling.

With these goals in mind, IKEA set about fulfilling its paper needs. Three major European paper suppliers were chosen who could provide a TCF paper without using old-growth forest fibers: Italy's Burgo, Finland's Finpap, and Kymmene. The paper used in the body of the different versions of the 1993 IKEA catalog was lightweight coated TCF paper, with weights ranging from 51 to 61 grams. The cover stock was a TCF board, ranging in weight from 175-200 grams. It was purchased from Finnboard in Finland and Stora Billerud in Sweden. The paper used for inserts was also TCF.

IKEA is very happy with the final result of using TCF papers for the entire catalog. TCF is slightly less expensive than the papers used in earlier years. Compared to the lightweight coated paper used in the past, the TCF paper had a brightness that was 2 percent lower — a percentage that is hardly noticeable. There is a visible improvement in its opacity compared to papers with similar weight that were used previously.

All of the rotogravure printers IKEA used, reported that both runability and printability were as good as or better than in previous years. This year, IKEA printed the different European versions of its catalog at major printers such as Gruner & Jahr, Burda and Broschek in Germany, Ringier in Switzerland, and ILte in Italy. In North America, IKEA printed its American and Canadian versions at Donnelley in Casa Grande, Arizona, and Brown in Franklin, Kentucky.

Looking into the Future

IKEA founder Kamprad once said, "Most things still remain to be done — a glorious future!" Although an important step has been taken by switching the entire catalog to a TCF paper, there are still other challenges to be met to make the catalog even more environmentally friendly.

The inks, glue, and lacquer used in the catalog printing and binding process do not pose any obstacle to recycling printed catalogs. IKEA has finalized an arrangement to recycle printed catalogs in the United States and Switzerland. Many IKEA retail organizations in other countries are in the process of looking for means to recycle printed catalogs. The most natural step now will be to promote the development of an equivalent TCF paper that contains a greater amount of postconsumer recycled fiber. IKEA hopes to reach that goal within two years.

Panel 2:
Publishers and Printers

Question and Answer Session

■ **Kathie Emmett,** *State of Washington, Department of Ecology:* I have a question to which any of the panelists may respond. Do any of you, as buyers, have requirements in your contractual agreements concerning your suppliers' adherence to State and Federal environmental regulations or pollution prevention activity?

■ **Unidentified Speaker:** The answer is yes.

■ **Kathie Emmett:** Can you specify these, or do you just ask them if they are in compliance with State and Federal regulations? How do you phrase the question?

■ **Roger Telschow,** *Ecoprint:* The general contract clause provides for the supplier to be in full compliance with all Federal and State laws. We call that the boilerplate clause. On a personal note, having been brought up in a paper mill, though not literally, of course, I perhaps have a little better understanding of how you comply with some of these rules and regulations. I was responsible for dealing with the regulatory agencies in one company I worked for. Now I go on regular mill tours, periodically. I go where I want to go, not where the managers want me to go. And we ask the resident managers questions; for example, what is your history? What type of violations have you had? We know that everything is fallible; only the things a god makes are infallible. So they do have accidents and upsets. If they don't tell me about it, I'll read it in the paper the next day, anyway. I think that our companies, our suppliers are doing an excellent job. If we all managed our daily lives and homes the same way some of these mills are managed we would not be talking about environmental pollution today.

■ **Michael O'Rourke,** *IKEA, North America:* The same applies to IKEA. Although I'm not specifically involved in the procurement of printing capacity or the purchase of paper, I do know that IKEA requires that all its suppliers adhere to all legislation regarding the issue.

■ **Pete Radecki,** *Michigan Technological University:* I have questions for Ms. Taylor and Mr. Hopkins, and an open-ended question for Mr. O'Rourke. First, Ms. Taylor, I think some of the things that you've done with recycled products are very commendable, but I did detect something that concerned me. With regard to procuring materials that may enhance pollution prevention, if they increase the cost of your raw materials, you explained that it may be difficult for you to raise subscription rates to satisfy those costs. Can you tell us what percentage of your revenues come from subscription rates and whether or not it would be possible to satisfy those costs by increased costs of advertising in your magazines?

■ **Kit Taylor:** I can't tell you specifically what our revenue is from subscription rates, but it's slightly under 50 percent, I believe. Not slightly under, it is below 50 percent, somewhere between 20 and 50 percent. What we want is for subscribers to reinforce our commitment to the extra expense. Since our advertising dollars have been going down over the last few years it's not going to come from there. The cost of paper's going up; the cost of goods in general is going up. So we need to recover that money somewhere. Publishing is not an incredibly profitable industry.

■ **Pete Radecki:** Thank you. Mr. Hopkins, you mentioned that you hadn't received any formal requests from readers for information about chlorine-

free products. I'm not that familiar with your business, but if I were to pick up a copy of *Popular Mechanics*, for example, and I wanted to find out something about the TCF products used in that particular magazine, would I see Hearst in there somewhere or would I write to *Popular Mechanics* under some other letterhead?

■ **Don Hopkins,** *Hearst Enterprises:* Yes, in both instances. You could address the letter to *Popular Mechanics*, or — on the masthead, as we call it in the business — you would find that it's published by the Hearst Magazine Division of the Hearst Corporation and any inquiry of that nature would come through our system, whether by telephone or letter. It would eventually get to the people I talked to in preparation for this meeting. They tell me, however, that they do not remember any call or query of that type. Now whether or not some editor may have received a written question and didn't think it was important enough to bark up the system, I wouldn't know. But, in fact, this is not an issue among some 300 million readers of our magazines.

■ **Pete Radecki:** Mr. O'Rourke, I think IKEA's catalog is fantastic and I'm not saying I'm on the chlorine side or the nonchlorine side. But the fact that you are out there making an honest effort to do things environmentally sound is excellent. I'm curious; do you have similar types of aggressive measures that you're pursuing with regard to the products that you sell in the catalog — as to how they're produced? I know that's a bit outside this conference, but maybe just a few comments that you might want to share with us.

■ **Michael O'Rourke:** As I stated earlier, the catalog is just one of many environmental issues that IKEA is working on. I can refer to Margaret Rainey of Greenpeace and the long cooperation that we've had with them on a number of other matters. PCB, for example, was a subject that we looked at very closely. I'd be happy to refer you to the officer in the company who is involved with environmental policy who can fill you in on more details.

■ **Gayle Coyer,** *National Wildlife Federation:* I have a question for Mr. Hopkins. You made the point that a lot of your decisions are based on scientific information. I'd like to know if you and your company are monitoring the dioxin reassessment that is currently underway, and if you and your company are prepared to change your paper procurement specifications based on the outcome of that reassessment.

■ **Don Hopkins:** First of all, I said I rely on the scientific information that is provided to me primarily through trade publications and the media. I read some of the same journals that the gentleman from Conservatree talked about earlier this morning. I am aware that there is a reassessment of the impact of dioxin in mill effluents taking place. I'm not aware of how extensive it is or whether it's before or after the many changes in the cooking and bleaching processes that have been described here. I'm familiar with one study that measured dioxin going into Lake Superior in a stream before the stream was affected by papermaking facilities. At one point, the dioxin level was higher there than in that same stream below the chemical pulp-mills. So, we're trying to keep abreast of the information and the art that's out there. We will, as always, do what's best. We are environmentally conscious citizens. But more important, I think our suppliers will address the issue so it will not become a factor for us.

■ **Gayle Coyer:** Is there going to be a decision for your company at some point that will reflect the outcome of the dioxin reassessment that is currently underway?

■ **Don Hopkins:** You're suggesting that the study will conclude in black and white. I frankly doubt that will happen. I suspect that a conclusion will be reached that may or may not be different from prior assessments. The people who are responsible for making the changes will see that we cannot stop publishing magazines and newspapers — well, newspapers aren't a factor — but magazines and books because somebody says that the paper we're using may have a problem. We can't just stop publishing. So what we need to do is wait for that day to happen, work with our suppliers, and come up with a logical and sound solution. The emotional issue cannot control the publishing business. Otherwise, we would go into something else. You know, we could make furniture or something. I think you're asking me to come to a conclusion that is truly impossible.

■ **Gayle Coyer:** No, I raised this issue because you made quite a point of saying that you believe your papers are environmentally friendly. If new information comes to light, such that your papers may not be environmentally friendly, are you prepared to make changes? That is the issue I was trying to explore.

■ **Don Hopkins:** We will always use the best available paper for our products.

■ **Tim Martin,** *Greenpeace:* I have a question and a comment for Mr. Hopkins. The question is very brief. Are you the person to write to in the Hearst Corporation?

■ **Don Hopkins:** Yes.

■ **Tim Martin:** The comment is this: I think you raise a false dilemma in terms of unbleached paper. No fashion magazine, no high-color printing job wants to be on unbleached kraft. That's not the dilemma that exists; it's not the dilemma that Greenpeace or any other environmental group raises. Obviously, the quality of the IKEA catalog and many other publications exemplifies that. So I'd just like to warn you that I think you should be careful about how you raise the issue. Because I think you're rather purposely misleading.

■ **Richard Phillips,** *International Paper:* Mr. Hopkins, I don't think you intended to say this, but you indicated that the EPA dioxin reassessment was aimed at the paper industry. It's not. It's an overall scientific reassessment of the potential human health hazards from dioxin. The paper industry accounts for less than 1 percent of all the toxic equivalents of dioxin that are produced in the United States annually. There's a draft document out now on exposure to dioxin in the environment; it's about 600 pages long and the paper industry occupies less than a page in it. I just wanted to set the record straight, in case you're confused on that issue.

The Implications of Sustainable Development for the Forest Product Industry

Peter E. Wrist
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A major change has taken place over the past few years in the public's attitude toward the forest products industry in general, and the pulp and paper industry in particular. Until very recently, the public praised the industry's products for their versatility, low cost, cleanliness, and for being made from a renewable raw material. Steady progress was also being made in reducing the known environmental impacts of our industries' effluents.

This sudden change in public opinion is largely the result of a major campaign — global in nature, well financed, and skillfully managed — that has capitalized on a heightened environmental concern among an affluent generation in the developed countries. The effects of this change in some of our industry's markets and operations have been dramatic. Market pulp specifications in Germany are no longer limited to properties of the pulp required to satisfy its intended use; they now require certification that strict environmental performance standards have been implemented at the mill that produces it, and assurance that sustainable management practices are being followed in the forests from which the fiber comes. Now it is proposed that the pulp supplier be required to fund the collection and recycling of the products after customer use. To paraphrase Germany's Environment Minister, "You no longer sell pulp in Germany — you merely lease its use."

Restoring a positive public image requires not only maintaining our product quality, but also assurances that we are managing forests and operating manufacturing processes in an environmentally sustainable manner. Above all, we must do a better job of communicating our processes and improvements to the public, so that it can be more knowledgeable about our industry.

Sustainable Development

Sustainable development gained worldwide prominence in the 1987 report, "Our Common Future" by the United Nations World Commission on Environment and Development. Chaired by Gro Harlem Brundtland, the Norwegian Prime Minister, this international committee found that unchecked endemic poverty and population growth in the underdeveloped nations is as much a long-term threat to the global environment as economic development.

Technology and social organizations, the Commission argued, can and must be managed and improved so that a sustainable environment can coexist with the economic growth required to provide the world's basic needs of food, clothing, and shelter, and to extend to all peoples an opportunity to fulfill their aspirations for a better life. The Commission did not underestimate the magnitude of the world's problems; it issued an urgent plea for prompt action by governments and individuals to make the necessary changes in technologies and social systems that would make sustainable development a reality.

Sustainable development is defined in the report as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. The concept, therefore, implies a limitation on the nature and direction of development: the ac-

tivity must be sustainable. It rejects, however, the concept of finite limits to growth (Meadows et al. 1972), believing that today's limits can be expanded as our technology and environmental and social understanding increase. This improved understanding will undoubtedly lead to changes in current lifestyles. But changing the lifestyles of people in the developed countries will not be sufficient to raise the living standard in the developing countries; we must also increase the productive capacity of the world's ecosystems.

Although the sustainable development concept has been adopted by many countries and organizations as a basis for future action, support has not been unanimous. Some groups have dismissed sustainable development as a contradiction in terms. For them, the only acceptable policy focuses on the preservation of the environment and rejects economic development. Their political agenda calls for a permanent reduction in the current worldwide consumption of natural resources, and a more equitable distribution of the residual (Kroesa, 1991). They appear to reject the possibility of enlarging the pie through prudent resource management and technological innovation.

At the other end of the spectrum are those who continue to seek economic growth without concern for environmental sustainability. They have not accepted the change that has occurred in the public's values, and they react with surprise and anger when their behavior is challenged. Today's battles over environmental issues arise primarily from the incompatibility of these two extreme points of view.

A wide divergence of views still exists on the full implications of the sustainable development concept and on how we can best develop policies and actions to achieve it. Not withstanding the May 11, 1992, cover of *Business Week* proclaiming "Growth vs. Environment," a recognition on all sides is growing that sustainable development is not an exercise in tradeoffs between economic development and environmental protection, where a gain on one side is a loss on the other, but a cooperative endeavor in which both the environment and the economy are beneficiaries (Smith et al. 1992). Decisions based on maximizing economic efficiency without concern for long-term industrial environmental effects or vice-versa by some environmentalists and regulators is no longer appropriate.

Process and Recognition

Today's complex environmental and economic problems cannot be solved by changing our accounting procedures to include additional values for a variety of environmental costs and benefits. Though this suggestion could improve the economic efficiency of our decisionmaking, it fails to deal with two fundamental issues that are part of the Brundtland vision (U.N. World Comm. Environ. Dev. 1987). The first is that development today should not compromise the ability of future generations to make their own choices, the *intergenerational equity* issue. The interests of future generations cannot be taken care of by simply changing accounting practices.

The second issue is the public demand to include a large number of noneconomic factors in the environmental decisionmaking process — factors such as maintaining the diversity of plant and animal species, public recreation, preservation of ecosystems, and the wide range of social goals, cultures, and religious beliefs that exist concerning the use of forest systems. In a democratic system, resolving the conflict among societal goals is the task we delegate to politicians and bureaucrats rather than economists or scientists.

How does this political process work? And is there a role for good science in the process? Eric Ashby (1992) described a useful but simplified model of the process. He observes that during an issue's first phase, politicians usually ignore it until it reaches emotional proportions triggered either by the persistent actions of a crusader, for example, in the case of pesticides, by Rachel Carson's *The Silent Spring* (1962); or by a life-threatening accident, for example, by persons eating food contaminated by a toxic chemical spill (Kuratsune and Shapiro, 1984).

While these crusaders or "initiators," as Ashby calls them, may dress their arguments in scientific terms, it is the sensational element in their message, not its scientific accuracy, that grabs the attention of the public and eventually the politicians. Ashby, a renowned biological scientist himself, reluctantly admits that a crusader who "stretches" science a little may even be excused at this stage for his or her efforts to gain the public's attention.

Issues and Challenges

Once the issue gains public attention, it enters a second phase, as Ashby points out. Advocates on either side of the issue present their arguments: one side emphasizes the threats to the environment; the other, the costs of making the proposed changes. Both sides will use, and occasionally misuse, "science" to support their arguments. During this public debate, the scientist and the economist have an important role to play. If they can avoid the role

or the appearance of advocacy, they will inform the public and provide politicians and bureaucrats (who must eventually make and implement public policy) with the best information available. That is, they help the policymakers better understand the issues involved before they have to reach a final decision.

Even with good scientific and economic input, some information is always lacking and the eventual political decision will involve as much political instinct as logical analysis of the scientific and economic facts. If, however, the scientists or economists have done their job effectively, the decision is less likely to be in conflict with available scientific knowledge. Once the political policy and goals have been established, a further opportunity arises in a third phase for technical input to guide the development of regulations that will achieve political goals in the most economical manner possible.

Pollution prevention is the preferred and, in the long run, the most economical solution, and closed industrial systems are an optimum goal. But pollution prevention technology is not available to solve every problem, so pollution control processes (end-of-the-pipe treatment) are an essential part of effective, timely, and responsible environmental protection. And economic technology is not the only limiting factor. Limited resources and other competing economic demands also prevent quick solutions to environmental issues.

A sustainable development strategy must therefore include setting priorities so that the most important issues can be tackled first. If resources are applied to issues of low priority, they are unavailable to address more critical problems. Continuing research and development must be used to fill important factual gaps and improve future priority setting and resource allocation. Good science has a role to play in both these areas.

The Forest Products Industry and Sustainable Development

Recycled fibers do not grow in garbage dumps; they start their lives in forests as virgin fiber. The Brundtland vision of sustainable development involves more than the management of forests for sustained yield. Sustained yield is a harvesting policy that limits the annual allowable cut in a forest at a level below its estimated average annual incremental growth. This practice, already widely used in the major pulp producing countries, is a necessary but insufficient requirement for maintaining sustainable development in the forest.

Sustained yield prevents the overexploitation of the forest resource through timber harvesting, but it does not address the need for improved forest management practices to protect biodiversity. It cannot deal with the issues of uneven age distributions and overmature stands, or with ways to improve the productivity and quality of the resource. Sustained yield gives no answer to the question of how society's new demands for multiple uses of forest resources can be made compatible with increasing fiber demands and with periodical harvesting of the resource. Sustainable forestry must deal with all these issues.

The public's shopping list of services to be provided by the forest continues to increase. In addition to providing the raw material for timber uses, today's forest managers must also meet demands for

- watershed management and soil conservation,
- recreation of various kinds,
- preservation of wildlife habitat on land and in rivers and lakes,
- preservation of genetic diversity,
- moderation of global climates and rainfall patterns,
- achieving global management over greenhouse gases such as carbon dioxide, and
- remediation of impoverished farmland and cut-over areas that have not been successfully regenerated.

And the list continues to grow. Satisfying these demands will require new forest management policy and practices. One such technique being developed is the "ecological planning method" in which clearcutting, a practice required for the regeneration of many commercially valuable species, is limited to small acreages that follow the natural contours of the landscape (Hägglund, 1992).

This practice reduces the possibility of soil erosion and runoff of nutrients into the streams and lakes. The clearcut areas are interspersed with islands and corridors of older trees that provide cover for wildlife and help restore biodiversity to the forest after replanting. Clearcutting is an issue that raises powerful images and emotions. Perception often overrules understanding on both sides of the debate, and the need exists to promote better understanding and communication on why and when this forest management technique is appropriate and environmentally sound.

An alternate approach, the practice of "soft forestry," is often advocated by environmentalists as the only acceptable sustainable system. Soft forestry involves selective harvesting, natural regeneration, and the use of soft-footed harvesting equipment. From an economic viewpoint, soft forestry's disadvantage is that timber productivity per hectare is low and costly using this method. It may, however, be an appropriate alternative for some public forests and private wooded lots where policy has decided that nontimber uses are to be given highest priority. In many areas, knowledge necessary for the optimum application of these improved forest management programs for different forest types is still lacking and must be developed by ongoing research.

Intensively Managed Plantations

Do intensively managed plantations have a legitimate place in a sustainable forest policy? This is an issue of much disagreement between some foresters and environmentalists. Plantation proponents believe that timber production on a limited number of small sites close to the manufacturing mills allows diversity of use and species to be better maintained over wide areas remote from the mill that may then be managed less intensively for multiple use. Proponents cite the examples of intensive management of eucalypt plantations in Brazil (Campinhos, 1992), or the *Pinus radiata* plantations of Chile (Delmastro, 1992) and New Zealand (Dyck, 1992).

Their opponents insist that all forests must be managed to retain their "natural" state. Plantations of limited species, even with a wide diversity of provenances to maintain a large genetic pool, they claim, are not sustainable in the long run (Hogarth, 1991). This "natural forest" approach limits the opportunities to enhance the stock genetically or to raise the productivity of the forest significantly above that of the natural forest.

In the absence of sufficient research to resolve these issues, we need a mix of forest management strategies so that good data can be collected and analyzed for each different approach. In a mixed approach, sites of outstanding ecological diversity could be set aside as permanent preserves. The extent of the areas set aside — whether 5, 10, or 15 percent of the total forest — is a matter of public policy. Indeed, the ratio should probably vary from one region to another depending on the uniqueness of the individual forests.

Other sites with suitable soil conditions and topography would become plantations, intensively managed primarily for timber supply, but with some multiple uses possible in the periods between harvesting. In many cases, these sites could be abandoned or be marginally economic farmland. The largest proportion of the forest, however, could then be managed less intensively for multiple use including an emphasis on maintaining the biodiversity characteristic of the natural forest.

Indeed, developing a diversity of management practices tailored to specific sites and uses may prove to be as important an objective for ensuring the future sustainability of our forests, and the ability of our forest systems to adapt to potential long range problems such as acid rain and global warming, as the goal of preserving the diversity of species and their genetic pools.

Maintaining the Genetic Pool

Fortunately, a start has been made to generate better information on forest genetics for future decisionmaking. Of particular importance is Gene Namkoong's pioneering work at North Carolina State University. He has developed breeding strategies that will not only enhance the quality of the forest stock, but also maintain its genetic diversity and resilience under changing climatic conditions (Namkoong, 1991).

The contents of a forest's genetic pool do not remain static over time. As environmental conditions change, so does the relative competitiveness of specific species or gene combinations. As a result, the frequency of different genes present in a forest ecosystem changes from one generation to the next. Namkoong stresses that we must not only maintain the gene pools that produce superior trees on fertile forestry sites; we also need to protect the genes that allow trees to survive in poor soils. Their ability to survive under stressful conditions may well make them the "future winners," if and when major environmental changes occur, for example, as a result of global warming.

The significance of this concept is illustrated in the work of last year's Wallenberg Prize winner, Donald H. Marx. Marx (1991) discovered a new way of restoring forest productivity to areas that have been badly degraded. The symbiotic role of mycorrhiza in tree nutrition and early life survival has been known for some time. Marx's contribution arose from a serendipitous observation that the mycorrhiza, *Pisolithus tinctorius*, which is normally a very poor competitor in good soil conditions, is able to tolerate high temperatures. He also found it does well in poor acidic soils, and tolerates high heavy metal concentrations. Today, seedlings inoculated with *Pisolithus tinctorius* are being successfully used to rehabilitate sites that had previously resisted reforestation.

The close interdependence of the entire forest ecology with soil and climate has been recognized by James P. Kimmins et al. at the University of British Columbia (1990), who are using ecological site type classification and indicator plant species to monitor the impact and long-term trends caused by management practices and climate change. Their research is already beginning to have its impact on British Columbia forest management and reforestation practices.

Fertilization Research

Fertilization, combined with hybrid breeding, has been the key to productivity gains in agriculture but has found only limited use in commercial forestry. Unfortunately, fertilizer and chemical use by farmers is a major source of water pollution in many places. Research on plantation fertilization by Torsten Ingestad, an earlier Wallenberg prize winner, has demonstrated that these adverse environmental problems can be avoided, and timber yields improved if application rates are carefully matched to the nutritional requirements of the trees at different stages of their growth (Ingestad, 1989). This practice has undergone field trials in Sweden and Iberia on forest plantation sites and promises to achieve greater productivity with lower chemical use and minimized environmental impact.

In another field, the recent studies of J.R. Sedell et al. (1988) on streams in the Pacific Northwest have drawn attention to the role played by large pieces of woody debris in streams, in determining the abundance and quality of fish habitat. Their findings illustrate the interdependence of sustainable forestry and sustainable fisheries and can help improve management practices for both resources. It is now recognized that during harvesting operations in the proximity of still or running water, not only must borders of trees be left to provide shade and a passage for wildlife but also woody debris must be left in the streams and mature trees and snags on the banks. Such debris provides fish and other aquatic organisms with the ecosystems and nutrients they need to propagate and prosper while the harvested forest is being regenerated. These examples of forestry research are representative of the kinds of knowledge that will make our forest management practices more compatible with the goal of sustainable development.

The Attack on Effluents

Pulp and paper mill effluents have recently come under heavy attack from environmental groups. As a result, my own Institute's research program has undergone a major shift over the past few years, from a focus on process modifications to reduce manufacturing costs and improve quality to a focus dominated by environmental issues. The Canadian pulp and paper industry is committed to the virtual elimination of persistent bioaccumulable toxics from its effluents. The Pulp and Paper Research Institute of Canada (PAPRICAN) has been assigned the responsibility for developing the technology to accomplish this goal and has entered into a jointly funded cooperative program with the Canadian government to do so. Although pollution prevention and system closure are the long-term goals, pollution treatment measures will also be needed in the interim.

Laboratory and field studies on environmental impact are being carried out to help guide the work. In addition to evaluating the effect of effluents on early fish larvae growth rates and ceriodaphnia reproduction, we are now including fish liver enzyme assays and studies of fish maturation and reproduction after lifetime exposure to effluents.

Process modifications, proposed by PAPRICAN and others (Luthe et al. 1992), have already allowed mills to reduce the previously low traces of dioxins found in their products and effluents below the background levels that are ubiquitous in an industrial society (Berry et al. 1992). As a result, chlorine use by the Canadian pulp industry has already been reduced by over 50 percent; oxidizing chemicals, such as chlorine dioxide, oxygen, ozone, peroxide, and activated oxygen, are being used as chlorine substitutions. Extended cooking and enzyme treatment are also being used commercially in some bleached pulp mills to reduce the quantity of bleaching chemicals required (Scott et al. 1992).

Recent research has shown that dioxins are present on most of the exposed surfaces we come in contact with in our daily lives, including recycled papers and containers. This contamination is most likely the result of atmospheric deposition from combustion sources such as incinerators and automobiles. Bleached kraft pulp made according to recommended technologies to eliminate dioxin formation typically contains less dioxin and furan than pulp made from unbleached and recycled papers. I believe that the issue of background levels will emerge as the determinant of achievable regulatory levels of dioxin in paper products and production effluents rather than changing levels of analytical detection. Airborne contamination from extraneous sources raises questions of how far one industry can be held accountable for removing a contaminant that is

caused by society at large, particularly a contaminant that eventually may require modifications in transportation systems to overcome.

Recycling Research

Goals are being set in most major developed countries for increased levels of product recycling, including grades of paper that previously had not been considered suitable candidates for incorporating recycled fibers. Over time, increased rates of recycling will moderate the demand for pulpwood significantly, and lessen demands on the forest. The industry is increasing recycling aggressively. The question remains whether recycling levels should be set by regulations or by market and economic forces.

Recycling is not simply an issue of fiber conservation but also involves fiber quality, energy use, health, sludge disposal, and other issues that argue against adopting a single uniform solution for all grades and locations. Research on recycling at PAPRICAN is focusing on better deinking processes and on ways to overcome the strength deficiencies of recycled fiber. Recycled fibers have lost some of virgin fibers' elasticity. This elasticity may lead to increased breaks on high-speed presses.

PAPRICAN is also tackling the challenges involved in finding ways to reuse or dispose of deinking sludges in an environmentally acceptable manner. Public acceptance of reduced product quality in papers made from recycled fiber is considered a transient situation and for most uses the market push for improved quality will return.

New technologies, including some based on recently developed membrane materials, are leading to novel ways to clarify and reuse process water. If these efforts prove commercially successful, environmental benefits will accrue through lower effluent loads and reduced energy consumption. The ultimate goal of all process research is a manufacturing operation that does not discharge any harmful wastes into the environment.

Pulp Producers' Opposing Positions

As mentioned earlier, sustainable development issues can rarely be solved by economic or scientific reasoning alone, although good science has a legitimate role to play. Two examples of ongoing debates concern the future use of chlorine compound bleaching and the pros and cons of incineration as an environmentally friendly way of managing the disposal of residual low grade wastepapers.

Two opposing positions have been taken by pulp producers in response to demands by some market segments for chlorine-free pulp. Such differences of response are healthy signs that we have a highly competitive industry and one in which the free market system is working well. Competition stimulates technological innovation, and this in turn may benefit both the customer and the environment. However, the danger exists that the development of technology by one company to meet the demands of one segment of the market may be indirectly imposed later by regulators on the whole market under the guise of best available technology economically achievable (BATEA) regulations solely because it is available.

The balancing of environmental benefits and the economic efficiency requirement embodied in sustainable development and the BATEA concept must be strictly followed in such cases. Regulations should respond to scientific evidence of environmental benefit rather than to perceptions, philosophy, or the availability of new technology developed to satisfy a niche market. Regulations must provide significant environmental benefits or they can lead to serious misuse of scarce resources.

Conclusion

The changed public perception of our industry is not a passing cloud that will disappear with the passage of time. Rather, it is a reflection of a major and lasting shift in public expectations and values concerning the environment. The actions needed to regain public confidence in our industry and to achieve the goal of sustainable development go hand-in-hand. Significant changes in forest management and manufacturing operations have already occurred. Much progress has already been made, and a commitment exists to continue research and development toward the long-range goal of sustainable development. The role of good science in sustainable development is to provide the signposts and tools to define problems and to set priorities for their solution. Although political judgment remains an important part of the decisionmaking process, good science can help ensure that we use limited resources for solving the important problems first.

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Market Pulp and the Environment — Issues in Perspective

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Market pulp is used in a vast array of products and places, and the consumers of market pulp products have specific quality and performance needs. These facts combine to create a very complex market situation. No single formula describes all the needs that customers of market pulp have. However, some common trends can be discerned, and these will be the subject of this presentation. My objective is threefold: first, to describe the market pulp business in general and how it relates to demands for environmental quality; second, to delineate customer needs, and what customers really want in the environmental arena; and third, to present Weyerhaeuser's response to these issues, including our view of the future as it relates to environmentalism.

The Market Pulp Business

Market pulp represents 20 percent of the world's total bleached paper grade pulp capacity (Fig. 1). Thus, 80 percent (or 140 million metric tons [tonnes]) of paper grade pulp produced today is only indirectly influenced by market forces. On the capacity side, bleached kraft represents about 82 percent of the total market pulp capacity (Fig. 2). Not surprisingly, most of my comments will focus on the environmental requirements of bleached kraft market pulp.

Incidentally, the size of the paper grade pulp market is about 25 million tonnes, nearly half of which is sold to Europe (see Fig. 3). Events in Europe are therefore critically important to the entire pulp market. However, as shown in Figure 4, more than half of the paper grade market pulp produced today comes from North America.

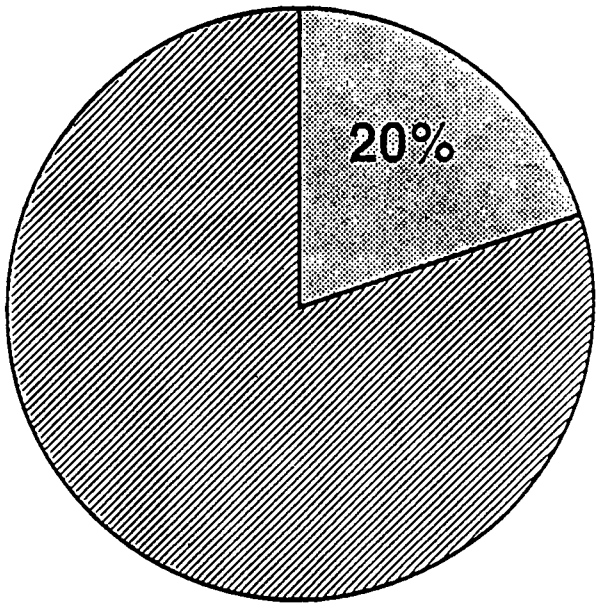


Figure 1.—Market pulp portion of total global capacity of bleached paper grade pulp (1992).

Weyerhaeuser's Role in the Market

Weyerhaeuser's market pulp division produces approximately 2.1 million tonnes of fluff, papermaking, specialty, and dissolving pulp. Approximately 65 percent of these products are exported to Europe and the Pacific Rim. With the recent acquisition of the Grande Prairie and Flint River operations, Weyerhaeuser is the world's largest supplier of market pulp, serving more than 75 countries. Our facilities are distributed throughout North America, spanning most of the major commercial forest regions. Thus, we have a wide variety of fibers that

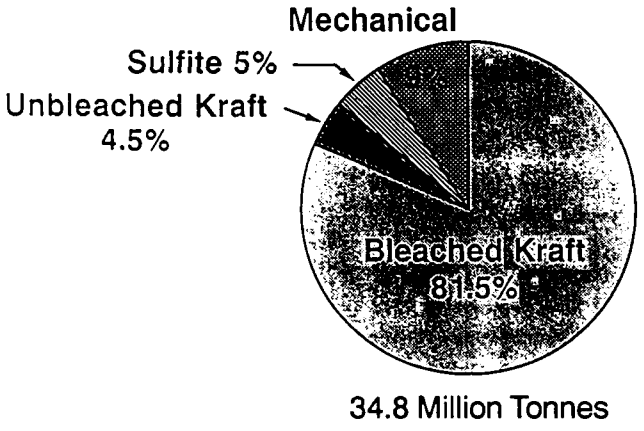


Figure 2.—Global paper grade market pulp capacity (1992).

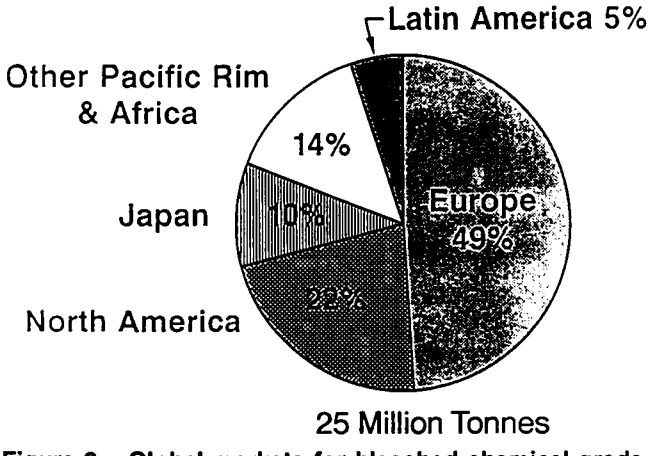


Figure 3.—Global markets for bleached chemical grade pulp (1991).

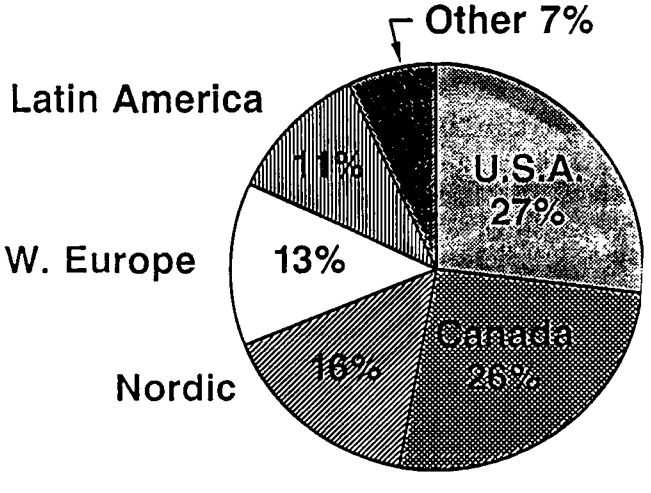


Figure 4.—Global sources of bleached chemical paper garde — market pulp capacity (excludes former Soviet Union and PRC).

find their way into a large number of applications — an unparalleled breadth of market exposure.

We also have a significant division that was responsible for collecting 1.8 million tonnes of recycled fiber in 1991, from 23 recycling centers in 20 States. This division is growing rapidly.

What Do Customers Really Want?

Fiber suppliers, papermakers, publishers, and distributors share concern and some confusion about customers' environmental needs and demands. We're all in this together, and none of us can claim to fully understand where the environmental demands are going. Nevertheless, we have been working together for some time to anticipate the needs of consumers and to develop strategies to address their concerns. Some of the factors involved in this complex situation include recycling, forest management, and chlorine bleaching. These are the "big three" issues for market pulp customers. Recycling and forest management are perhaps the most familiar; I'll discuss them briefly before dwelling somewhat longer on the details of chlorine bleaching.

Recycling Is Working

What is the market message on recycling? "Just do it!" Recycling is a global ethic. It has tremendous appeal to individuals because recycling is something that people can do personally to benefit the environment. This appeal explains the rapid expansion of recycling practices; it also ensures that the issue is not going to fade away. Of course, there are environmental questions associated with recycling that are simply not considered in this global thrust to increase recovery rates. For example, "life cycle" issues need to be resolved, such as the cost to transport recycled material over long distances, the fate of sludges that come from deinking processes, and the safety of recycled food containers.

Notwithstanding these concerns, recycling continues to grow. Figure 5 shows a steady decline in the ratio of pulp to paper and paperboard capacity from the early 1970s to the present, largely as a result of recycling, combined with increases in paper filler content. This figure is an excellent example of source reduction in action. Paper contains substantially less virgin fiber today than it did 20 years ago.

How has this trend influenced Weyerhaeuser's business? Figure 6 shows the rapid increase in recycled fiber sales volume that we experienced from 1975 to 1991 and project through 1995. We expect our recycled fiber sales to double between 1990 and 1995.

I can also report a dramatic increase in the use of recycled fiber within the company. By 1998 we anticipate using recycled fiber in amounts

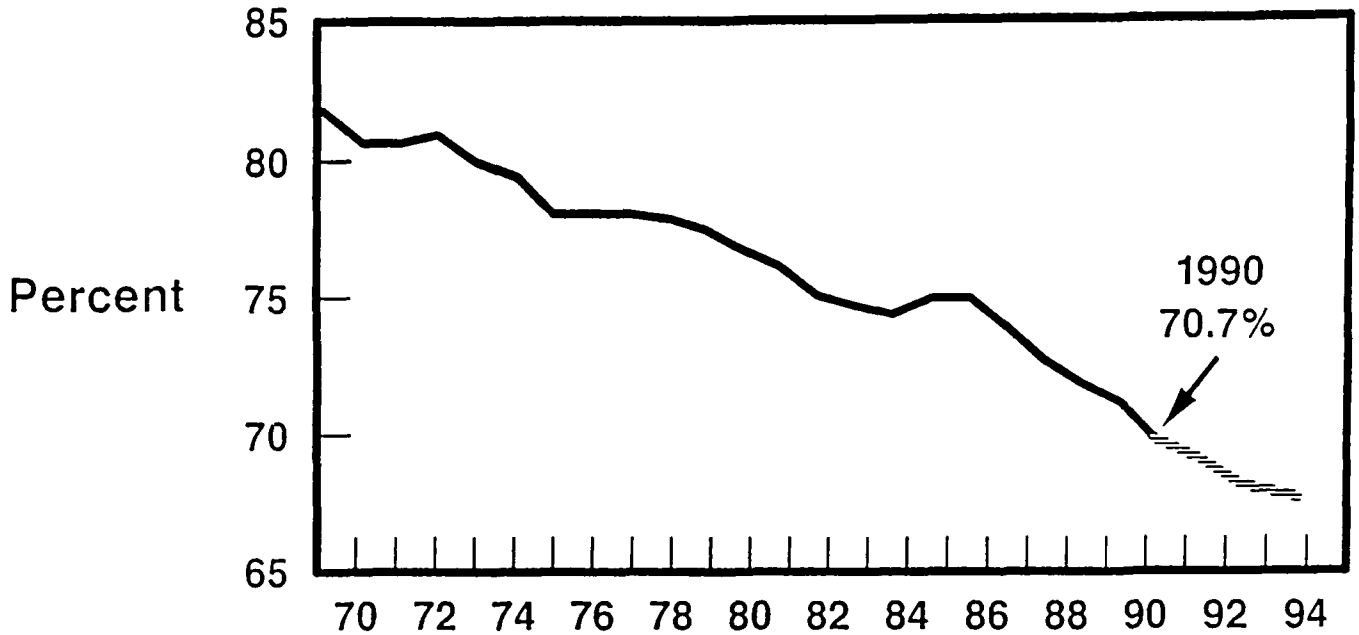


Figure 5.—Ratio of paper pulp to paper and paperboard capacity.

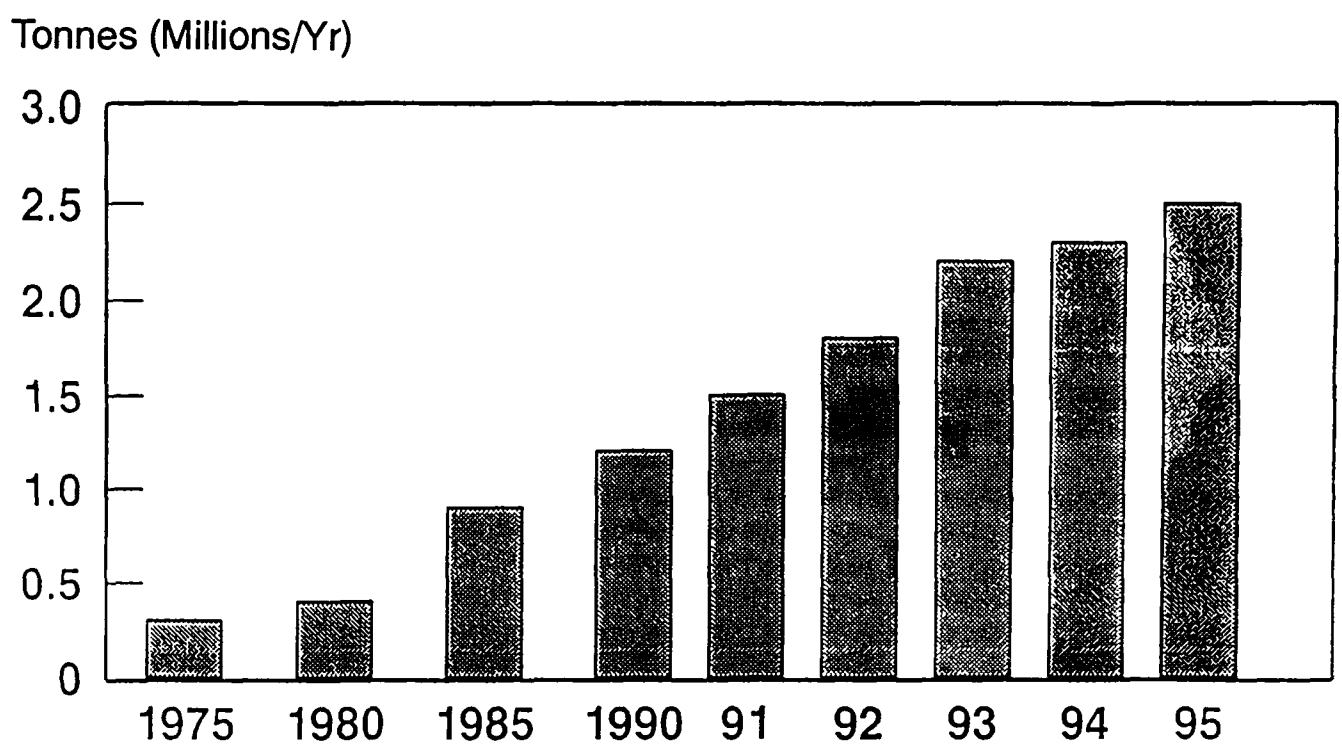


Figure 6.—Weyerhaeuser recycled fiber sales.

equivalent to the output of eight kraft pulp mills, each producing 800 tonnes a day (see Fig. 7).

The pulp and paper industry is moving rapidly toward its goal of a 40 percent recovery rate industrywide by 1995. The voluntary, market-driven actions that are being taken are working well. We are concerned, however, that mandated recycling legislation could hamper this positive trend. With the market working well, we feel it would be a mistake to disrupt this positive trend.

Forest Management Issues

Forest management is another issue currently in the minds of many consumers. Let me review the key market messages we are receiving from the public on this issue.

First, we are being asked to practice sustainable forestry. That concept, however, is not well defined. We are also being asked to maintain the biodiversity of the forest. Again, the meaning or definition of

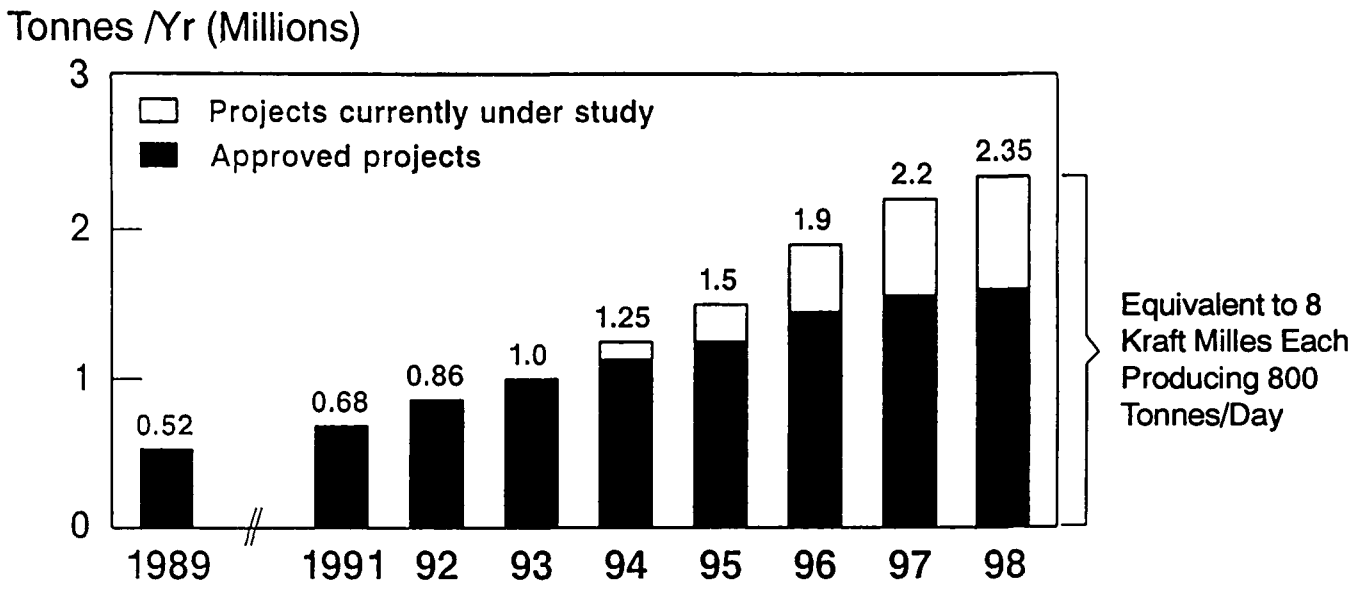


Figure 7.—Weyerhaeuser recycle fiber usage.

biodiversity is not clear. A final important message that we are receiving from the market is that we should protect "virgin" forests, though no one has clearly defined what a virgin forest is. These are serious issues that we are actively addressing, but much work needs to be done to better articulate their significance.

To summarize Weyerhaeuser's view, we believe that commercial forests can be managed on a sustainable basis to provide

- clean water,
- wildlife and fisheries habitats,
- recreational opportunities, and the
- aesthetic value of the forest.

We also recognize the importance of maintaining biodiversity in managed forests. We see managed forests as an important complement to the biodiversity being sought in wilderness areas, national parks, and other reserved federal lands.

Well-managed commercial forests will enable society to reserve more public forestlands for noncommercial uses. We need to focus our efforts on deriving maximum benefit from the forests that we use as a way of protecting the forests that we set aside.

Without doubt, wood is a renewable raw material that can be used to meet the basic needs of a growing world population. If not wood, what? Of course, we have much to learn about forest management issues stemming from the market, but we're well on the way to defining the issues.

Chlorine Bleaching, an Evolving Issue

The market message on chlorine is clear: "don't use chlorine for bleaching." Right now, this message has reached maturity primarily in Europe. The issue is mostly driven by events in Germany; however, those of you who know the European market realize that no major market in Europe is independent of the others. What happens in Germany essentially happens in the rest of Europe. There are no major European producers of paper or other consumer products that do not have significant customers in Germany.

The evolution of this issue began in Europe. A brochure emerged from Sweden in the late 1980s. Its title was "Paper and the Environment"; its primary author was Göran Bryntse. This brochure detailed the deteriorating quality of the Baltic Sea.

Bryntse proposed in this pamphlet a three-tiered rating system designed to evaluate the "environmental friendliness" of papers manufactured in Sweden. He assigned an "A" rating to "chlorine-free" paper from manufacturers with effluent bearing less than 0.1 kg of adsorbable organic halogens (AOX) per tonne of pulp, and a "B" rating to "low chlorine paper," containing less than 0.5 kg AOX per tonne. Anything above 0.5 kg per tonne was referred to as chlorine paper. Note that dioxin is not mentioned in this rating system. To this day, dioxin is not a major issue in Europe.

It is also interesting to note that the brochure represents a paradigm shift from concern about product quality to a more global concern about environmental protection in the place where the product is manufactured. This shift represents an important development.

With this evolution, a nomenclature emerged to describe the various bleaching options now being used in Europe. At the first level is an elemental chlorine-free (ECF) option. In this option, no chlorine gas is added to the bleaching process; however, other chlorine compounds may be used.

The next, more stringent level is referred to as low AOX pulp. This pulp may contain anywhere from 0.1 to 0.7 kg AOX per tonne of pulp depending on the individual customer's needs. The highest designation, the ultimate goal for some is a totally chlorine-free (TCF) pulp in which no chlorine compounds at all are used for bleaching.

Although the ultimate goal may be TCF for some European markets, the industry currently does not have the capability to make TCF pulp at acceptable brightness, strength, and cost levels. This incapability has created tension in the marketplace and fostered a search for alternatives.

Going back to Bryntse's alphabetical rating criteria, papermakers are seeking a bridge to TCF by researching a low chlorine option that allows them to achieve a gradient chlorine-free status along the way to TCF. Their approach is to create formulations combining kraft pulp having some low level of chlorine and other TCF components such as chemithermomechanical pulp (CTMP) and filler, giving a net 0.1 kg AOX per tonne in the paper sheet. With this kind of formula, the kraft pulp itself may vary as required to provide this target level in the paper. This may sound like hocus pocus — clearly it is marketing and not science — but it is real and represents a true reduction in chlorinated organics along the way to TCF.

Chlorine Bleaching Today

Customers in North America and Japan are showing growing interest in the chlorine issue and particularly in ECF products, but as yet this market is not widespread. In Europe, ECF is required in most places; however, demand for low AOX pulp is rapidly emerging as the next step. This option arises out of the industry's inability to meet TCF demand.

With this in mind, we need to consider the availability of totally chlorine-free bleached market pulps. Table 1 illustrates that while some volume of bleached CTMP and sulfite pulp is available in a totally chlorine-free form, only a small proportion of kraft pulp (the majority of pulp on the market) is available as TCF. This number is growing, but it will take some years to reach a supply level sufficient to meet the demand.

Table 1.—Availability of totally chlorine-free bleached market pulps (May 1992).

GRADE	GLOBAL MARKET CAPACITY** (1992)	TCF PROPORTON
BCTMP	2.10	Virtually all
Sulfite	1.88	At least one third
Kraft	28.40	2.5%

*Excludes former Soviet Union and Peoples Republic of China
**Millions of tonnes

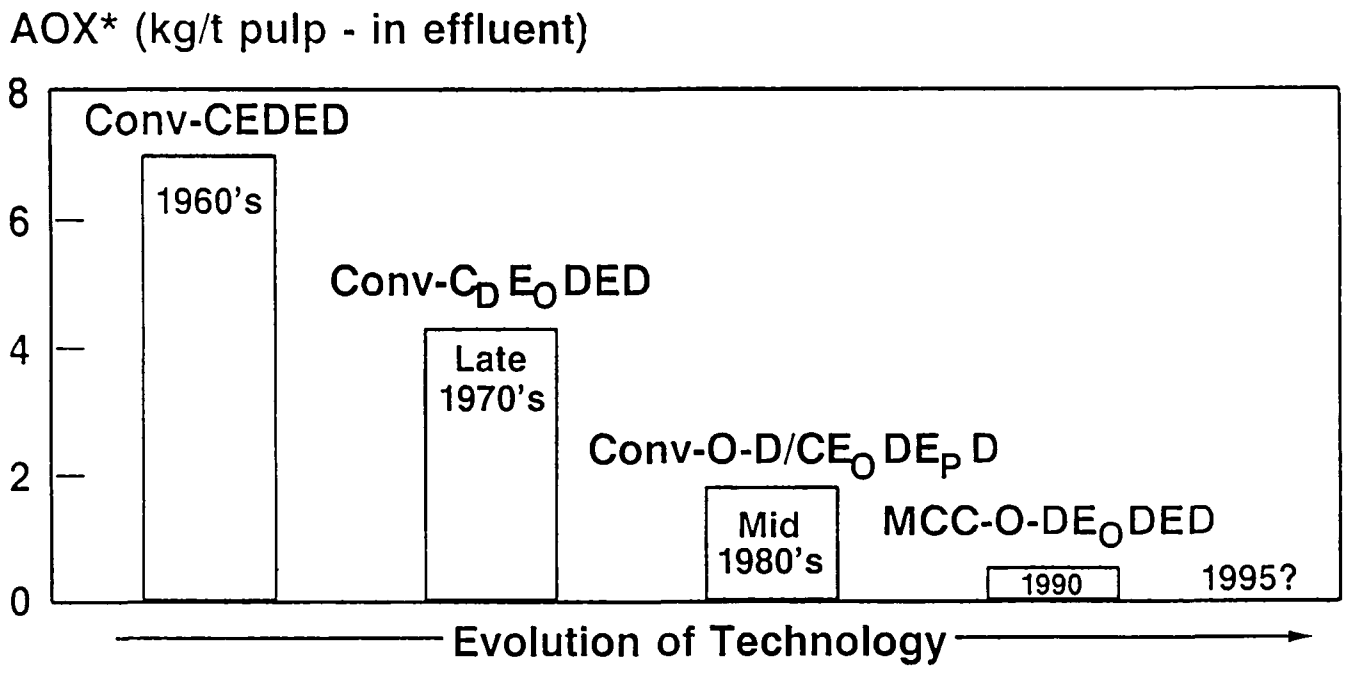
The first constraint on the achievement of TCF is product quality. Do not underestimate the importance of this factor. Brightness and strength are primary barriers to TCF today. For most mills, it is not possible to use TCF processes and achieve mandated brightness targets. Of equal importance is our inability to maintain acceptable strength levels at economical production speeds. Thus, product cost becomes a constraint. Only experience and technology can help us overcome the production factors affecting these key product characteristics.

The second major constraint to achieving TCF is technology. Most mills do not have the capability, and those that do require further technological advancements to overcome the brightness and strength issue.

Third, even as the technology emerges, is refined, and becomes widely available, significant capital is needed to convert from traditional bleaching and pulping processes. A pulp mill is a closely linked network of interrelated, highly complex systems, and major changes to any portion of the system affect the entire mill. Those impacts must be thoroughly understood and accommodated before TCF production can become routine. Understanding, experimentation, and accommodation take time, our fourth constraint.

Despite those constraints, our manufacturing processes are evolving toward TCF. Figure 8 traces the evolution of kraft pulp mills over the last 30 years. Note how the state of the art has changed in terms of bleaching sequences and the resulting acceptable AOX levels. Advancements in technology and processes have already made vast decreases in AOX levels while retaining full brightness and strength levels, yet market concern for AOX did not arise much before 1990. No doubt the added impetus of those market concerns, combined with further exploration of such alternatives as extended delignification and ozone, will continue this trend into the next decade.

This progress will not be easy, quick, or inexpensive. Table 2 shows the magnitude of the quality reductions and cost increases we must manage and overcome to follow that trend. As we move along the spectrum from conventional bleaching processes to ECF and low AOX pulp to TCF, the quality decreases by about 10 percent at each step beyond ECF, and the costs increase in far greater increments. Nor do capital expenditures alone suffice; chemical costs increase significantly, leading to higher overall manufacturing costs. (This is but one example; depending on specific product and manufacturing processes, the case can be much worse than depicted here.) The result, as I've men-



*These AOX levels assume full pulp brightness and strength

Note: AOX does not correlate with toxicity

Figure 8.—The state-of-the-art kraft mill.

tioned before, is that TCF requires an enormous capital investment and does not yet meet customer quality needs. We still don't know either the capital or the manufacturing costs of producing TCF at the brightness and strength levels that customers will require.

Right now there are some European customers who want TCF, but only at acceptable product quality and cost levels, neither of which we can currently deliver. To get there, pulp manufacturers will need to build a bridge, an intermediate step. Efforts are already underway, and it appears that chlorine dioxide will play a vital role in that transition.

Even chlorine dioxide, however, is likely to be transitory. The demand for TCF in the European market is driving the elimination of bleaching done with chlorine and assorted chlorine compounds though the pace of change is currently determined by the limitations of technology and the economics of quality and cost. As we make headway against those limitations, TCF demand is likely to spread to the rest of the world, where chlorine bleaching is not yet a major market issue. It appears to be only a matter of time.

To recap the major market issues:

- Recycling is moving rapidly and successfully, and we feel it can be best continued without mandates.
- Forest management is an emerging issue that involves a positive story about renewable resources. There is no doubt, though, that we must better understand the issues surrounding biodiversity and resource management. We must examine our management practices closely and continuously improve them.
- Chlorine bleaching, primarily a European concern, is an area in which we have made tremendous strides but have a long way to go before technological and quality limitations allow us to fully meet demands for TCF. In the meantime, ECF should be recognized for the huge positive step that it provides.

Table 2.—A mill example.

	CONVENTIONAL	ECF	LOW AOX	TCF*	TCF
Brightness	90	90	97	75*	85+
Strength	100%	100%	93%	88%*	100%
Cost of bleaching chemicals	base	+20%	+50%	+50%	?
Capital requirement	base	$6 million	$14 million	$14 million	>$100 million

*This TCF quality does not meet customer needs

Issues to Anticipate

Additional issues on the horizon include energy use, odor, and water use. The first is energy use. As life cycle analysis becomes better understood, energy will play a larger role in critiques of environmental performance. The second is odor. Despite our increasingly sensitive measurement and recovery systems, this long-standing community concern won't go away soon. Finally, water use, like energy use, is an additional area of concern as the availability of clean and plentiful water becomes more constrained in many communities. These issues require our consideration now if we are to understand and address them properly as they arise.

The Forest Products Cycle

The answers to these issues lie within the forest products cycle that begins with the harvesting and replanting of trees and progresses through production to consumer use, recycling, composting, conversion to energy, and appropriate use of landfills before starting all over again. We are fortunate to be working within an industry that uses a renewable resource in a myriad of ways and efficiently satisfies both customer needs and the environmental and social concerns engendered by our manufacturing and disposal methods. We should be proud of our record and our accomplishments within this cycle — proud, but not satisfied. As the cycle keeps coming, we can always do more to improve our performance in every arena, including environmental performance.

Our goal should be to maximize the forest products cycle, with "no-effect" manufacturing as the ultimate goal. We don't claim to have all the answers, but among the answers are the following:

- sustainable forestry, providing fiber from manufacturing residuals and trees grown for the purpose of making pulp;
- energy self-sufficiency in closed-cycle processes, manufacturing methods with low water use and the recovery of chemicals for reuse;
- recycling after use and clean conversion to energy or compost of those fibers that cannot be recycled; and finally
- the return of ash or compost to the land to become part of the next forest cycle.

This ongoing, sustainable, and successful cycle will, if properly managed, result in environmental responsibility, economic sustainability, and success. The environmental issues that we face today — recycling, forest management, and chlorine bleaching — are integral to the cycle and will help determine the evolution of the pulp and paper industries over the next decades. With an ultimate goal of "no-effect" manufacturing, and a perspective that encompasses these issues within the framework of the whole forest products cycle, we can manage the pulp and paper industry's evolution into an improved and improving future.

Market Barriers for Aspen Bleached Chemithermomechanical Pulp Products in the United States

Patricia J. Dollar
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Slave Lake Pulp Corporation is the result of a partnership formed by Alberta Energy Company of Canada and MoDo of Sweden, to construct a 350 tons per day bleached chemithermomechanical pulp (BCTMP) mill using state-of-the-art equipment and technology. The mill is located in Slave Lake, Alberta, Canada, surrounded by vast reserves of aspen timber. Scandinavian paper manufacturers have long had an unparalleled worldwide reputation for being on the leading edge of environmental risk assessment and risk management.

The Slave Lake pulp mill uses self-regenerating aspen forests in northern Canada. From initial manufacturing processes to the finished pulp, all details are selected for minimum environmental impact. The process does not use chorine or chlorine dioxide but a two-stage peroxide bleaching process.

The aspen species used in the BCTMP manufacturing process has a low lignin content fiber, which is highly suitable for use by the high-grade paper manufacturers who are the mill's targeted customers.

The BCTMP process results in a high-yield pulp (trade name: Ranger), with an 88 percent average yield that is almost twice that achieved by a conventional kraft process. The aspen fiber also has a brightness level of 85 ISO, which makes it suitable for use in coated and uncoated free sheet paper grades.

Aspen BCTMP Fiber Replaces Hardwood Kraft Pulp

Aspen BCTMP fiber is designed as a replacement for hardwood kraft pulp in the manufacture of commodity and high-grade printing and writing papers. Aspen BCTMP has a zero purity rating of 82 percent, freeness ranges of 75 to 350 Canadian Standard Freeness, and consistently meets brightness ranges of 85 to 86 percent ISO.

BCTMP processing technology provides the paper manufacturer with a pulp that produces surface smoothness, good bulk characteristics, and excellent opacity. In addition, in coated paper grades, the surface coating eliminates potential color reversion. The results of many tests and end-user feedback confirm that brightness reversion is no longer the issue that was originally associated with early generation high-yield pulps.

Adding aspen BCTMP enhances the bulk and stiffness of recycled grades, which are usually notorious for their limpness. Copier papers in particular benefit from the enhanced performance and stability that comes from the addition of aspen BCTMP to the furnish. BCTMP also helps to offset reduced brightness levels in deinked fiber, which levels have long been a complaint in copier papers. Some possible cost advantages are also gained by adding BCTMP to recycled furnish. Depending on the amount of virgin kraft or recycled fiber replaced, cost savings on the manufacturing side

can help to reduce the current disparity in price between virgin and recycled papers.

Demand for Aspen BCTMP in the United States

Aspen BCTMP is marketed mostly in Europe, the Far East and North America for a variety of end-use applications such as copier papers, forms, bond, and high-grade coated papers. Some of the demand in Europe and Japan result from the fact that BCTMP is totally chlorine-free — those markets also have a much greater familiarity with high yield pulp in general. However, despite successes in Europe and the Far East, to date, there has been surprisingly limited market penetration for aspen BCTMP in North America.

Papermakers cite wood-free definitions as their primary reason for not using this product. They refer to existing definitions used by the government and adopted by the pulp and paper industry. As most of us know, these definitions limit the use of "mechanical pulp," "groundwood," or lignin. Now, aspen BCTMP does contain lignin — albeit only 17 percent versus the nearly 28 percent that is found in groundwood pulp — but according to harmonized tariff definitions, it is not a "mechanical pulp." In fact, in these definitions, nonbleached chemithermomechanical pulp (CTMP) is included as a "semichemical pulp."

The industry needs, I think, to rewrite some definitions and to be more specific about others. For example, the Joint Committee on Printing (JCP) specification used by the U.S. Government Printing Office (GPO) limits the groundwood content in certain grades (to a maximum of either 10 or 1 percent). Clearly, BCTMP is not groundwood. However, GPO uses the phloroglucinol test to detect groundwood, yet this test identifies lignin and can therefore be used to exclude BCTMP from inclusion in government procurement. My understanding is that the JCP specifications do not define "groundwood" or mention BCTMP as a nonacceptable pulp. Many U.S. specifications and standards are written around old technology and are preventing the adoption and use of pulps from newer technologies.

Canada is Adopting New Standards for BCTMP

The Canadian General Standards Board (a federal committee) is in the process of adopting new standards that have no limits on the amount of BCTMP in wood-free grades bought through government procurement. In comparison, the U.S. government, by default, is creating real but unnecessary trade barriers to the advancement of sound environmental pulp and papermaking technology by not helping to create procurement opportunities for BCTMP. Slave Lake Pulp Corporation has approached many U.S. paper manufacturers, but mills are reluctant to purchase BCTMP as long as their products will be considered as groundwood-containing papers that do not meet Federal procurement standards.

Lignin-free Permanent Papers Controversy

Several organizations in their zeal to set standards and insure the permanence of papers have chosen to adopt or propose standards demanding that permanent papers be lignin-free. While I am squarely in their corner regarding the deterioration of paper, we must not forget that we are in an industry of constantly evolving technology (otherwise papermakers would still be down by the river pounding papyrus on rocks). Part of technological advance involves changes in pulping and bleaching processes. By today's standards and testing procedures, lignin is an unwanted label. But this notion is based on outdated information and makes no allowances for new processes. The end-use performance of BCTMP-containing papers has not been closely examined. Currently laboratory testing methods merely detect lignin, which is clearly not an accurate measure of the potential value of BCTMP pulps.

Those who are involved in the permanent papers issue would probably agree that the paramount objective is to avoid the physical degradation of the paper. BCTMP papers have been shown to meet this need. In the United Kingdom, for example, papers containing up to 15 percent BCTMP have recently been approved by a committee for buyers of archival papers. This approval will become part of a long-term test on the performance of BCTMP-containing papers. Independent tests have shown that alkaline coated and uncoated papers with up to 60 percent BCTMP (of the fiber) are equal to free sheet for retention of physical characteristics in accelerated aging tests. As previously mentioned, interest in BCTMP outside the United States is growing because buyers are concerned about chlorine use in traditional chemical pulps. Consequently, we need to do all that we can to encourage the growth and development of new technologies that produce better papers in an environmentally friendly manner and provide cost savings.

Incentives should begin with changing the freesheet and groundwood standards as presently written, or with the creation of a third standard for

BCTMP pulps. It is imperative that we eliminate the "guilt by association" attitude that currently has BCTMP and semichemical pulps categorized with newsprint and other groundwood grades. Evidence from many test runs and commercially produced papers dictate otherwise. In the past decade, the Federal Government has become a leader in promoting the use and procurement of recycled papers. Now, the Federal Government needs to provide additional incentives, including the creation of specifications for grades of paper that will allow the use of BCTMP pulp in federally procured finished goods.

One Company's Experience with Chlorine-free Bleached Pulp (a Cautionary Tale)

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Export Sales
Fraser Paper, Limited
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Requests for chlorine-free pulp and paper appeared in the European markets from about 1986 on, as a consequence of suggestions by some environmental groups that dioxins and other chlorinated organics, present in minute quantities in paper and pulp mill effluent, might be harmful to users of bleached paper and to consumers of fish, living in bodies of water receiving such effluents.

This notion found strong resonance, principally in Germany and Scandinavia, for reasons best analyzed by political scientists and students of ethnic psychology. Significant segments of the pulp and paper industry in those countries, and in countries pursuing trade in Scandinavia and Germany responded positively. They made the necessary investments to offer elemental chlorine-free (ECF) and totally chlorine-free (TCF) pulps for the manufacture of so-called chlorine-free papers.

Fraser Paper, which owns a magnesium bisulfite market pulp mill in New Brunswick, Canada, was one of the early producers to have 100 percent TCF capability and was, I believe, the first in North America to produce TCF chemical pulp. Today, that mill is shut down and being offered for sale.

Given the "clamor" for TCF pulps and chlorine-free papers, many ask, "what happened?"

Fraser Paper's TCF Experience

Our experience may be useful to others who are trying to respond to changing market trends and so-called market opportunities. Market pulp is an industrial intermediate product, sold by pulp producers to paper manufacturers. These producers are typically companies of significant size; they are also technically competent and commercially astute. Ordinary transactions are quite large. As a consequence, when pulp buyers speak, pulp salespeople listen!

As we look down the product chain, market complexity increases, with more options and players involved. For example, printing and writing paper passes through several stages of conversion and distribution, which are often independently managed or owned.

I mention this complexity to show the difficulty one has when faced with an evolving situation. Initially, the demand was made for chlorine-free papers, then chlorine-free pulps, then for pulps bleached without chlorine, then pulps bleached without chlorine compounds (see Table 1).

Table 1.—Common environmental acronyms.

ACRONYM	DEFINITION
"Green"	"Environmentally correct" white pulp
ECF	Elemental chlorine-free
CGF	Chlorine gas-free
CCF	Chlorine compound-free
CCF (again)	Chemical chlorine-free
NCC	Nonchlorine compound
MCF	Molecular chlorine-free — technically the most accurate term to use for pulps that have nevertheless been bleached with chlorine dioxide
ACF	Active chlorine-free
ACF (again)	Absolutely chlorine-free
ACF (yet again!)	Almost chlorine-free
TCF	Totally chlorine-free — now the accepted term to characterize pulps that have involved no chlorine compounds at all in their bleaching processes

Now, oxygen, ozone, peroxide, enzymes, and other methods are being considered for pulp bleaching. But is this what the market *really* wants?

Understanding the Market

What is the market? Is it the ordinary consumer buying a roll of toilet paper; the secretary making a xerographic copy; the owner of a small print shop printing menus for the neighborhood restaurant; the purchasing manager of a large publishing house buying tens of thousands of tons of paper per year; or the environmental activists' vision of what "ought to be"? I don't know — probably all of them!

As noted earlier, certain segments of the world paper industry responded quickly to the chlorine-free bleaching issue, especially Germany, which has no kraft pulp mills, only sulfite mills; and some Scandinavian countries, where there are a number of older sulfite mills. In all cases, the countries had strong environmental movements.

The sulfite pulping process has not maintained its share of the total chemical pulp produced and in those terms has been in decline for some time. The technologically, economically, and environmentally more advantageous kraft pulping process dominates the world industry today. Sulfite pulps are best used in special applications that make good use of sulfite's unique fiber properties.

Sulfite pulp is easier to bleach than kraft pulp. Therefore, the conversion of a sulfite bleach plant to an ECF or TCF bleaching process is relatively simple, not too costly, and results in product quality approaching that of conventional chlorine-bleached sulfite pulps. Many in the sulfite industry saw an opportunity to enhance their market position and improve their future prospects by converting or building plants to produce ECF and TCF pulp.

Two things happened. First, most of the European sulfite producers reached the same conclusion. Today virtually all of the Western world's sulfite market pulp capacity has ECF potential, and I estimate that probably half, if not more, has TCF capability, for a total capacity of nearly 1.8 million metric tons.

Second, they expected that the one, clear, unquestioned virtue of having truly chlorine-free pulp would neutralize the technical differences between sulfite and kraft, thus permitting sulfite pulp to recapture market segments lost to kraft pulps. Well, where are we now?

In Germany and the surrounding countries, pulp buyers have accepted TCF sulfite pulps for applications in which sulfite fiber performance compares to that of kraft — primarily tissue and some printing and writing applications. Pulp import statistics for 1990 and 1991 bear this out, reflecting an increase of sulfite pulp imports to Germany (see Fig. 1)

Many buyers, however, continue to demand kraft fiber properties, principally strength, without sacrificing brightness and cleanliness. In a market

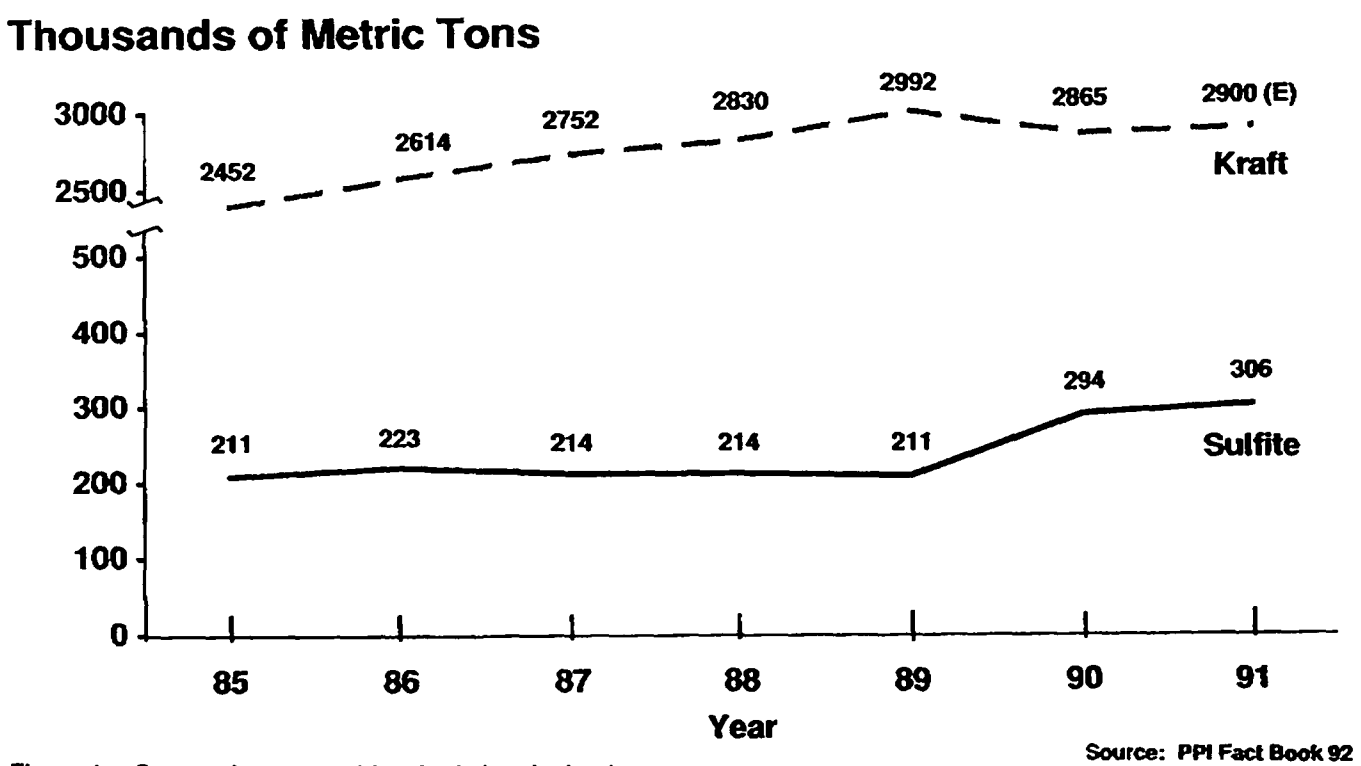

Figure 1.—German imports of bleached chemical pulp.

in which paper specifiers are unwilling and unable to compromise on product quality, the pulp buyers have no choice. The economic status of the pulp market during the last two years has contributed commercial elements to this competitive situation. In other parts of the world, the market for chlorine-free pulps is very small and limited to some very specialized applications.

Conclusion

Some people say, "the market is always right." I say "be sure you really understand the market." Leadership, or being ahead of the crowd, does have its advantages and, sometimes, disadvantages.

Seemingly interchangeable, similar products can have nuances both subtle and important. In some applications, substitution of sulfite for kraft fibers and vice versa is possible and practical. In others, only a strong economic incentive will create a change. In still others, substitution is not a realistic expectation. It is vital to understand the economic and technical implications of each situation.

Given the broad spectrum of fibers required by the paper industry, a market does exist for sulfite pulps. But whatever bleaching process is selected by each mill to respond to changing needs, the basic fiber properties defined by the wood species and cooking process will continue to count.

Market and Technical Aspects of Totally Chlorine-free Bleached Kraft Pulp in Europe

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The European pulp and paper industry is in the middle of the fastest and most dramatic quality change it has experienced in the past few decades — the move from chlorine bleached to totally chlorine-free (TCF) bleached products. The change is driven by environmental pressure groups and political decisions. Market demand has also forced this technical evolution and, today, most sulfite pulps are totally chlorine-free at high brightness levels. During the past year, even totally chorine-free kraft pulps at high brightness established a market segment.

Södra Cell has three mills in southern Sweden — in Mörrum, Mönsterås, and Värö — with a total production capacity of 1 million tons of bleached kraft pulp. Approximately 40 percent of the production is hardwood (birch); the other 60 percent is softwood (spruce and pine). This year about 15 to 20 percent of our production was in TCF grades, bleached without chlorine or chlorine dioxide. All our production is market pulp, and 75 percent of it is exported. Our customers are mainly located in central Europe. Today we produce softwood pulp at 80 percent ISO and hardwood pulp at more than 80 percent ISO. In September 1992, Södra Cell started the production of kraft hardwood pulp at full brightness (88 to 90 percent ISO) and totally chlorine-free. Ozone, peroxide, and oxygen bleaches are used instead.

The Evolution of Totally Chlorine-free Pulp

Long before environmental marketing was a reality, environmental protection was a top priority for the pulp industry. Chlorine bleaching produced toxic and heavily colored effluents that resulted in a large consumption of oxygen in the receiving waters.

In Sweden, earnest environmental protection work began in 1974 to minimize the negative effect of pulp bleaching. Before then, chlorine gas consumption had increased in tandem with increased pulp production. The first oxygen bleaching plant was installed in 1973; from 1974 to 1991, chlorine gas consumption decreased from 270,000 tons per year to less than 35,000 tons per year. Today all Swedish kraft pulp mills have installed oxygen delignification equipment. I doubt whether any chlorine gas will be used in Sweden after 1993 for bleaching pulp.

International Agreements

The public's "chlorophobia" has, of course, had an impact on the politicians. In 1988, the Swedish Parliament decided that "discharges of stable organic chlorine compounds from pulp and paper mills are to cease entirely." In 1990, the Nordic Ministers of the Environment came to a similar agreement.

The Third International Conference on the Protection of the North Sea agreed that "all substances that are persistent, toxicant, and liable to bioaccumulate should be reduced to levels that are not harmful to man or nature before the year 2000." In 1990, Sweden, Norway, Denmark, Germany, the United Kingdom, Switzerland, France, Belgium, the Netherlands, and the Commission of the European Communities signed the agreement.

When environmental pressure groups, governments and the general public demand that pulp and paper be produced totally chlorine-free, the industry must certainly try to change production

methods. Environmental arguments in marketing are here to stay. New quality criteria have been introduced with arguments that do not affect the product but the production process. These criteria have initiated dramatic technical development that has never before been seen in the history of pulp production. Initially development work was focused on the reduction of adsorbable organic halogens (AOX) to low levels; today a zero AOX is the ultimate goal.

Totally Chlorine-free Bleaching

Chlorine-free chemicals are used in large quantities for the bleaching of mechanical pulps. For example, chemithermomechanical pulp (CTMP) is bleached with peroxide. In recent years, peroxide has been used for bleaching sulfite pulps to high brightness levels. Peroxide is also the chemical used for producing TCF bleached kraft pulps. The peroxide bleaching process, similar to CTMP bleaching, consists of two stages: the first is pretreatment with a chelating agent or an acid wash; the second is the actual bleaching stage in which the peroxide is charged.

All TCF kraft pulps are similarly bleached with peroxide. Commercial production started in 1990. Although production is small so far, it's steadily increasing; many mills have already announced that they are going to start production of TCF pulp.

Today's brightness level is about 80 percent ISO. For example, Södra Cell has both a hardwood and a softwood at 80 percent ISO brightness. Hardwood is relatively easy to bleach to more than 80 percent brightness; softwood is more difficult because its strength is an important consideration. Too high a peroxide charge will decrease the pulp strength. That's why we use the technique of extended cooking before the peroxide bleaching. Extended cooking yields approximately five units higher brightness with retained strength properties. Strength properties for TCF pulps are the same as for standard pulps.

The Ozone Alternative

The next challenge is to reach full brightness with chemicals that do not contain chlorine. On a laboratory scale, different sequences have been shown to give high or full brightness. The key factor in these sequences consists of at least one stage with ozone. Södra Cell's Mönsterås mill started ozone bleaching on a full scale in September. The pulp bleached with ozone, oxygen, and peroxide is totally chlorine-free. The hardwood pulp will reach full brightness, 88 to 90 percent ISO, and the softwood will achieve a high brightness. The bleaching system consists of peroxide and ozone at medium consistency at a production rate of 1,100 tons per day.

Entering the TCF era is another step taken for environmental reasons. In the 1960s, we closed down old sulfite mills. In the 1970s, we started oxygen delignification. In the 1980s, we began to abandon chlorine gas. Now, — in the 1990s — we shall eliminate all chlorine containing chemicals and produce TCF pulps. There's no reason to be threatened by development. Make it an opportunity instead!

Conclusion

Environmental pressure groups, governments, and the general public are demanding TCF products. This demand has led to the development of bright TCF pulps. It began with TCF sulfite pulps, but now kraft pulps are also available on the market. Today's TCF kraft pulps have a brightness level of 80 percent ISO. That brightness is sufficient for wood-containing papers; however, it is too low for many wood-free papers. It is necessary to increase the brightness to full brightness for the TCF grades. Many paper companies have said that they will produce TCF papers when pulps are available with the same brightness as chlorine-bleached pulps.

Södra Cell started to produce hardwood TCF pulp at full brightness in September. Later, we will also have softwood TCF at full brightness. I am convinced that within the next few years substantial amounts of TCF kraft pulps will be available at full brightness and strength from several companies. The only drawback to such TCF pulps will be the price. Production costs for TCF pulps are higher because the bleaching chemicals are expensive, and the investment cost is high. In the end, the general public must — and will — accept a slightly higher price for TCF products.

Panel 3:
Market Pulp

Question and Answer Session

■ **Med Byrd,** *North Carolina State University:* For Dr. Moldenius, could you comment on the cost differential between a TCF pulp and a standard pulp?

■ **Steve Moldenius,** *Sodra Cell AB:* I can't give you the actual prices since they are changing from day to day. The TCF market is its own market in the same way that hardwood and softwood are their own markets. But today, the price is about 15 percent higher for TCF grades, both hardwood and softwood.

■ **Med Byrd:** I just want to comment, I was traveling abroad recently and I saw an ad for your company in an airline magazine. It was very amusing; it said, "You're the customer, you're always right. You told us you wanted chlorine-free pulp. We don't think it's required, but we're going to do it." A pretty unique, pretty funny attitude, I think. I also have a comment for Ms. Dollar. I appreciate your comments about CTMP. Those of us at North Carolina State University believe that it plays a strong role in future market and future pulping operations. We just put in a 3.5 tons per day pilot plant, so we're hoping that you're right. But also, I think it's fair that if you look at everything in a systematic way, you always need to consider the energy input into a mechanical pulp and compare that to an equivalent electrical or electrochemical energy for chemical and other pulping demands. In some applications, that energy ultimately depends on your location and can really make a difference in how well a TMP or CTMP is received.

■ **Sheri Tonn,** *Citizens for a Healthy Bay:* Mr. DeCrease, I was really interested to hear you say that Weyerhaeuser was planning a pulp expansion. Can you elaborate on specifically what technology you're planning, where you're planning the expansion, and what you're going to do about pollution prevention?

■ **Dean DeCrease,** *Weyerhaeuser Company:* That's not really the reason I am here. I was explaining why Carl Geist isn't here. It's not an expansion; it's a purchase of two mills that are already in place.

■ **Sheri Tonn:** Which two mills?

■ **Dean DeCrease:** We can talk about the details later.

■ **Mary McKiel,** *U.S. Environmental Protection Agency:* Ms. Dollar, I wanted to thank you for your perception and your vote of confidence. Not everybody realizes that when a Federal bureaucrat is away from his or her desk, it actually decreases efficiency. But more important, in your talk you addressed the area of Federal procurement that is near and dear to my heart. Perhaps not everyone realizes that the GPO system of specifications and the Federal specification system are two different systems. There are overlapping areas of responsibilities, but GSA's area is much broader. If Barbara were here, I'm sure she would invite you to talk to the group in New York about some possibilities. I am not familiar with each of their 115 specifications to know whether our requirements preclude the use of the pulp you mentioned but I encourage you to talk with the New York people.

■ **Patricia Dollar,** *Slave Lake Pulp Corporation:* Yes, I'd like to make a comment on that. In my attempts to understand what is happening in government procurement we have come across the most interesting things and one is that we have a major problem in terminology and semantics on this issue. It seems that everyone from NISO, ASTM, GSA, and GPO have a mandate to help create

markets for environmentally friendly products, but how can we do that if there's a catch-22 in the procurement guidelines? If you're a procurement officer, you can only do what your guidelines allow you to do. So you're shackled by language that really needs to be looked into to allow a new consensus to form. And this problem is not only within the government; it's also within the commercial sector.

■ **Susan Poniatowski,** *University of Massachusetts at Lowell:* Ms. Dollar, I have not kept up with all the various conjugations in the area of mechanical pulping, but correct me if I'm wrong. Is BCTMP, Bleached Chemical Thermal Mechanical Pulp?

■ **Patricia Dollar:** Yes.

■ **Susan Poniatowski:** Can you tell us what the chemical treatment is and is it a prechemical or a postchemical treatment after the thermal mechanical?

■ **Patricia Dollar:** Well, may I defer that question to the gentleman next to me? I am not a chemist, or even a person who payed attention in her college chemistry class. Everyone here the first day spoke a language I don't understand. I can get through the alphabet, but when it comes to chemistry I defer to the man on my left.

■ **Unidentified Speaker:** You bleach after the refining.

■ **Susan Poniatowski:** Yes, I understand that the bleaching occurs afterwards, but I understand also that there is usually an application of some sulphur compounds either prior to or immediately after the actual refining?

■ **Unidentified Speaker:** That is sulfite, the "C" of CTMP. The chemical treatment with sulfite is a pretreatment.

■ **Susan Poniatowski:** Okay, exactly. My second understanding of the process is that there is no recovery cycle yet developed for this particular process. Is that correct also in the Slave Lake facility?

■ **Patricia Dollar:** I have to refer this question, also. We have a gentleman in the audience who is the technical director at the mill. I think he might know better than I what they're doing there. If you would stand up, Ben, please.

■ **Ben Gromberg,** *Slave Lake Pulp Corporation:* You are, I believe, correct. There is no recovery cycle today. One reason is that we use much weaker solutions of chemicals than was formerly possible in the chemical pulp industry.

■ **Susan Poniatowski:** If you're getting an 80 percent yield, what is happening to the 20 percent lignin, waste, and lost fiber coming off the pulp? How are you dealing with that environmentally, and what about the chemical that you cannot recover, which I assume goes out in the same waste flow?

■ **Ben Gromberg:** First, our yield is 88 percent, so we're talking about 12 percent and in our case, we use an activator sludge system to take care of the effluents.

■ **Susan Poniatowski:** And the sludge is . . .

■ **Ben Gromberg:** . . . dried and later on incinerated.

■ **Mark Floegel,** *Greenpeace:* I'd like to ask for two clarifications from Mr. Seton. I was delighted when your paper came on the market and sad to see it go. One of your sales reps told me you had a $120 million conversion cost. The figure he gave me to move from chlorine-based chemicals to non-chlorine based chemicals was $9 million. I was hoping that you could clarify that. The other thing I hope you will clarify is that during the entire time your pulp was on the market your sales rep was never able to give me any sales literature that said it was chlorine-free. So, to my consumer perception, you never marketed it as chlorine-free pulp or never discussed the chemical make-up of the pulp, which seems to me one of the reasons it failed, that you hid your light under a bushel. I was wondering if you could clarify this.

■ **Ladd Seton,** *Fraser Paper, Limited:* Number one, I did not mention any number at all in my talk about a conversion cost so I don't know where the $120 million came from, maybe from your conversations with somebody else. The second point, the $9 million, I can, in fact, confirm. That was the approximate amount of the investment necessary for us to go from ECF to TCF in our specific case.

■ **Mark Floegel:** Is that Canadian?

■ **Ladd Seton:** Yes.

■ **Mark Floegel:** Did you have sales material to indicate that it was chlorine-free?

■ **Ladd Seton:** Of course. Now, once again, let me clarify. The product of our mill was market pulp. It was not paper. I also happen to know the sales rep that you talked to. He was in fact helping you buy chlorine-free paper, which ultimately I think you

purchased from Lyons-Falls and I'm happy to tell you that Lyons-Falls used our TCF pulp to make some of your production. The only thing that I regret is that your orders were so modest and small; had you provided Lyons-Falls with bigger orders, they would have provided us with bigger orders for our pulp.

■ **Mark Floegel:** For that we need more Greenpeace members.

■ **Peter Radecki,** *Michigan Technological University:* This is directed to Dr. Moldenius. Regarding the creation of a plant that sounds rather flexible for both chlorinated and nonchlorinated products, and regarding the rest of the movement that you mentioned in Sweden and elsewhere in Europe — were any significant incentives provided by the Swedish government in the way of product specs, price supports, tax incentives, or anything along those lines to assist you in the design, development, and eventual entrance into the marketplace of TCF products?

■ **Steve Moldenius:** Nothing.

■ **Neil McCubbin,** *N. McCubbin Consultants, Inc.:* I wonder if Steve Moldenius would be willing to tell us how much ozone and how much hydrogen peroxide he expects to require to bleach to full brightness. Or is that a trade secret?

■ **Steve Moldenius:** So far, I don't know. We are starting September 1.

■ **Neil McCubbin:** You've obviously done pilot and lab work.

■ **Steve Moldenius:** Yes, we have used pilot programs, but I'd rather wait to see the full-scale operation.

■ **Neil McCubbin:** Okay, fair enough. Thank you.

Closing Remarks

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I want to thank Administrator William Reilly and Deputy Administrator Hank Habicht for their uninterrupted commitment to this symposium and for their personal and much appreciated support of me and my staff during the past 15 months. I also want to congratulate John McGlennon for his terrific management of the sessions; Libby Parker and Project Manager, Susan Krueger; Lisa Harris, who assisted them; and Abt Associates; Eastern Research Group (ERG); and JT&A. Thank you for a superb job.

Most of all, I want to thank the 60 or so speakers and the participants from industry and the environmental community who helped us recruit them. We have had a wonderful group here, and as your reward, I will not try to recap all 60 presentations! The proceedings will do that. But I am grateful to all participants and most especially to the speakers for their graciousness and dedication.

As you know, the U.S. Environmental Protection Agency (EPA) is reassessing the status of dioxin and other toxins, and we are committed to basing our decisions on the best publicly available peer-reviewed science. William Reilly has spoken many times about his belief in the compatibility between sustained economic development and environmental protection — with an emphasis on prevention.

This conference has addressed a small but a very crucial piece of the chlorine equation. We have talked about the technical and economic aspects of alternative bleaching technologies. We do not leave here with a simple one-size-fits-all answer. We do, however, now share a common experience and the same basic information.

I hope that this symposium will be the beginning of a habit of communicating with, instead of at, one another. In the future, we should be able to address scientific issues and the inevitable differences in our evaluations of scientific data with the same professionalism that we have demonstrated during this symposium in discussing technology and economics.

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August 18–20, 1992 • Washington, D.C.

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served as Trustee for the Bergen County Society of Professional Engineers from 1984 to 1986, and has been active in ASTM as Chair of the Electrical Pulp Committee. She holds an M.S. in chemistry and attended the Pulp and Paper Course at the University of Maine.

Kathleen M. Bennett

Vice President of Corporate Environmental Affairs
James River Corporation
Richmond, Virginia

As Vice President of Corporate Environmental Affairs for the James River Corporation, Kathleen M. Bennett oversees environmental, product, industrial hygiene, and analytical services. Prior to joining James River, Ms. Bennett was Director of Regulatory Affairs for Champion International in Stamford, Connecticut. She has been employed at the American Paper Institute and at other paper companies for 20 years. In addition, Ms. Bennett was appointed by President Reagan in 1980 to head the Office of Air, Noise and Radiation at the U.S Environmental Protection Agency (EPA), where she developed an administration policy on such issues as the Clean Air Act Amendments and acid rain. Upon leaving EPA in 1984, Ms. Bennett was appointed to the National Acid Precipitation Task Force to help conduct a ten-year study of acid rain. Ms. Bennett is a graduate of Manhattanville College in Purchase, New York.

Lauren Blum

Consultant
Environmental Defense Fund
New York, New York

Lauren Blum is a consultant to the Environmental Defense Fund's (EDF) Pulp and Paper Project, where she specializes in mill technology. Before joining EDF, she was an Associate in the Energy and Chemicals Group at Booz Allen & Hamilton, Inc., in New York. There, Dr. Blum worked on a range of strategy projects for senior management of chemical, pharmaceutical, and consumer products companies. She also worked as a Project Leader in the Microelectric Products Research and Development Group at the Shipley Company in Newton, Massachusetts, where she developed advance products for use by integrated circuit manufacturers and successfully introduced a new product to the market. Dr. Blum received a B.A. in Chemistry from Harvard University and a Ph.D. in Inorganic Chemistry from the Massachusetts Institute of Technology. She also holds an M.A. in Public and Private Management from Yale University.

John F. Church, Jr.

President
The Cincinnati Cordage and Paper Company
Cincinnati, Ohio

John F. Church, Jr., is currently President of The Cincinnati Cordage and Paper Company. He received an A.B. degree from Colby College in 1959 and a B.S. from Carnegie Institute of Technology in 1961. Employed by Cordage Papers in 1964 as a salesperson, Mr. Church was elected Executive Vice President of the corporation in 1974, and President in 1976, which post he holds today. He is a member of the National Paper Trade Association, Inc. (currently representing 675 to 700 companies with annual sales of $425 billion), served as its Chairman/Past Chairman from 1981 to 1983, and has been a member of the Advisory Council since 1984. He served as Chairman of the PAPER Foundation from 1985 to 1990. Mr. Church was elected Chairman of the prestigious Paper Distribution Council (the largest in the industry, comprising one-half mill and one-half merchant representation) in 1990. Mr. Church is a member, PDC Executive Committee (1991 to present); elected to Board of Directors, Distribution Research and Education Foundation (1990 to present); and is a Leadership Cincinnati Alumnus (1979); Quality of Life Steering Committee Chairman (1987). Mr. Church served as Chairman of Junior Achievement of Greater Cincinnati (1983 to 1985); has been on the Board of Trustees, Cincinnati Council on World Affairs, since 1981; is a member of the National Association of Wholesaler-Distributors (NAW); and was elected Secretary of that association in 1987, 2nd Vice Chairman in 1988, 1st Vice Chairman in 1989, Chairman Elect in 1990, and is currently serving as 1991 Chairman of NAW.

John L. Clement

Manager, Pulp and Paper Industry Marketing
Babcock & Wilcox Company
Barberton, Ohio

John C. Clement joined Babcock & Wilcox (B&W) in 1956; he is presently B&W's Marketing Manager for original equipment and turnkey projects for the pulp and paper industry, having previously held positions in design engineering, sales, and marketing. His career with B&W has largely been involved with the pulp and paper industry. He is a member of the Technical Association of the Pulp and Paper Industry (TAPPI) and serves on its Steam and Power Committee. Mr. Clement graduated from the University of Florida with a B.S. in Chemical Engineering and subsequently received an M.S. in Mechanical Engineering from the University of Akron.

Gerard P. Closset

Vice President-Corporate Technology
Champion International Corporation
West Nyack, New York

Gerard P. Closset joined St. Regis Corporation (later acquired by Champion International) as a Senior Staff Engineer in 1977. He subsequently became Manager of Coating and Printing, then Director of Materials and Process Technology, and was named to his current position in 1987. Dr. Closset is a member of the Board of Directors of the Technical Association of the Pulp and Paper Industry (TAPPI) and serves on the Board Research, Research Management, Finance, and Executive Committees. He has participated in national meetings, and his articles have appeared in the TAPPI journal. He is also a member of the American Institute of Chemical Engineers, serves on the Research Advisory Committee of the Institute of Paper Chemistry, and is a judge for American Paper Institutes's George Olmsted Award. In addition, Dr. Closset holds a patent on a method for adding moisture to a moving web. Dr. Closset previously conducted research at the School of Public Health at the University of Pittsburgh, Pennsylvania, and worked as a

Research Engineer at Westvaco. He received his B.S., M.S., and Ph.D. in Chemical Engineering from the University of Pittsburgh.

Richard N. Congreve

Group Vice President
Potlatch Corporation
San Francisco, California

Richard N. Congreve has been employed in the paper industry for 45 years. He joined Potlatch in 1962, serving in numerous management positions involving pulp, paperboard, and packaging. From 1975 to 1980, he was Vice President and General Manager of the company's Minnesota operations and the Northwest Paper Division, headquartered in Cloquet, Minnesota. Group Vice President since 1980, he is presently involved in areas of engineering, energy, and environment. Before joining Potlatch, Mr. Congreve spent 15 years with Container Corporation in Chicago. He left that company as General Manager of the Lake Shore recycled boxboard plant. Mr. Congreve is a member of the Paper Industry Management Association of the Pulp and Paper Industry, and serves on the boards of the National Council of Air and Stream Improvement and the Foodservice and Packaging Institute. Mr. Congreve received a B.S. in Chemical Engineering from Northwestern University. He is a registered engineer in Illinois, Idaho, Washington, California, Minnesota, and Arkansas.

Frank J. Consoli

Manager of Packaging Technology
SCOTT Paper Company
Philadelphia, Pennsylvania

Frank J. Consoli is Manager of Packaging Technology for SCOTT Paper Company. In this capacity, he is responsible for worldwide packaging development. Dr. Consoli is a member of SCOTT's Corporate Environmental Steering Committee, which has overall responsibility for corporate environmental strategies and policies. He also serves as SCOTT's representative to the Coalition of Northeastern Governors (CONEG) Source Reduction Task Force and to the recently formed Southern States Waste Management Coalition (SSWMC). He is SCOTT's principle contact for Life-Cycle Assessments, and participated in the August 1990 and February 1992 LCA workshops sponsored by the Society of Environmental Toxicology and Chemistry (SETAC). He currently serves on the SETAC LCA Advisory Group. Prior to joining SCOTT, Dr. Consoli was employed by the Procter & Gamble Company, where he held a variety of product and packaging development positions in the deodorant, hair care, laundry additive and paper divisions. He holds a B.S. degree in Chemical Engineering from the University of Massachusetts and a Ph.D. in Chemical Engineering from the University of Florida.

C. Roger Cook

Vice President, Environment
E.B. Eddy Forest Products Ltd.
Espanola, Ontario, Canada

A native of England, C. Roger Cook emigrated to Canada to join E.B. Eddy Forest Products as a Process Engineer. He has worked for the E.B. Eddy company for 16 years and currently holds the position of Vice President, Environment. Prior to joining E.B. Eddy, Mr. Cook worked in England as a Fisheries Officer and Chemist for the Lancashire and Western Sea Fisheries Committee. One of his early assignments was to carry out the environmental evaluation of North America's first oxygen delignification system that began operation in the E.B. Eddy Mill in Espanola in 1977. Mr. Cook has a Bachelor of Technology degree in Polymer Technology from Brunel University and obtained an M.S. in Environmental Pollution Control from Leeds University.

Michael J. Cousin

Director, Quality Processes
Georgia-Pacific Corporation
Atlanta, Georgia

As Director of Quality Processes for the Communication Papers Division of the Georgia-Pacific Corporation, Michael J. Cousin is responsible for the translation of customer needs and expectations, especially to the converting industries, such as envelope. Dr. Cousin joined Georgia-Pacific in 1989 as Manager, Paper Projects for G-P Chemicals - Research and Development, where he worked with paper producers to enhance the efficiency of chemicals used in the papermaking process. Recently he has held both marketing and technical positions in the Communication Papers Division of Georgia-Pacific and is actively involved with the introduction of recycled papers. Dr. Cousin began his career with Battelle Memorial Institute as a research scientist, developing both natural and synthetic polymer systems and evaluating emerging pulping technologies and their byproducts. He then spent several years with Mead Corporation, where he was involved in the evaluation and development of new product and process technology for a variety of paper and board products and directed the technical activities of a manufacturing operation. Dr. Cousin received his Ph.D. from the College of Forestry, University of Washington, where his research focused on the production and evaluation of degradable polymer systems for use in reforestation.

Erin Craig

Corporate Environmental Programs Manager
Apple Computer, Inc.
Cupertino, California

Erin Craig is a Corporate Environmental Programs Manager for Apple Computer, Inc., in Cupertino, California. At Apple, she facilitates corporate environmental improvements, provides technical guidance to environmental efforts, and coordinates environmental regulatory and legislative tracking. Prior to joining Apple in 1990, she worked as a regulator of onshore and offshore oil developments; she was also an environmental consultant and researcher in air quality and hazardous waste.

Dean DeCrease

Director of Technical Service, Pulp Division
Weyerhaeuser Company
Tacoma, Washington

Dean DeCrease is Director of Technical Service, Pulp Divison, Weyerhaeuser Company. A graduate of Penn

State and Northwestern University, he has been involved in design and production of fine and specialty papers since 1976. Mr. Decrease joined Weyerhaeuser's Pulp Division in 1988 as Product Development Manager and in his present position also has responsibility for overall coordination of customer technical service.

Jeffery D. Denit

Deputy Director
Office of Solid Waste
U.S. Environmental Protection Agency
Washington, D.C.

Jeffery D. Denit is Deputy Director, Office of Solid Waste, at the U.S. Environmental Protection Agency. In addition to supporting the Director in managing this diverse operation, Mr. Denit has senior management responsib ility in areas of hazardous air releases from treatment systems, large volume wastes such as from mining activities, and the Subtitle D Nonhazardous Waste Program. Mr. Denit joined EPA in 1970, holding managerial positions in ORI and the Office of Water. During this period he managed all major areas of effluent guidelines for industrial water pollution control regulations. Previously Mr. Denit was a Civil Engineer and Economist with the U.S. Department of Agriculture and a Sanitary Engineer at the Federal Water Pollution Control Administration, U.S. Department of the Interior. From 1968 to 1970, he was a Captain in the U.S. Army, and Post Sanitary Engineer at Fort Ord, California. Mr. Denit has received many awards for outstanding performance, including the EPA Bronze and Silver Medals. He is listed in *Marquis Who's Who* and is a member of Gamma Sigma Delta. He has published numerous articles and reports on industrial pollution and public policy and administration, and is coauthor of the Water Pollution Control Federation Pretreatment Manual. Mr. Denit is a member of the Water Pollution Control Federation, the American Water Works Association, and the American Chemical Society. He received a B.S. in Agricultural Engineering and an M.S. in Agricultural Economics, both from Clemson University, South Carolina. He also holds an M.S. in Sanitary Engineering from the University of North Carolina.

Richard J. Diforio, Jr.

Vice President, Environment, Health and Safety
Champion International Corporation
Stamford, Connecticut

Richard J. Diforio, Jr., is Vice President, Environment, Health and Safety for Champion International Corporation, a manufacturer of paper for business and industry as well as plywood and lumber. In this position he directs corporate loss prevention and environmental affairs. Mr. Diforio joined Champion in 1965 as a Sales Representative for Fine Papers based in New York City. He was named Market Manager for fine papers in 1971, Coated Paper Sales Manager in 1972, and District Manager for Fine Papers in 1977. During the 1980s, he served as vice president of several divisions, including Sales and Order Services for Packaging Products, Planning and Development for Sales and Converting Operations, Business Management for Fine Papers, and Environmental. Prior to joining Champion, Mr. Diforio was a sales representative with the A.B. Dick Company and was also employed as an underwriter with Chubb, Inc. Mr. Diforio received a B.A. degree from Williams College.

Patricia J. Dollar

Consultant
Slave Lake Pulp Corporation
McLean, Virginia

Patricia Dollar is an independent consultant specializing in the area of recycled and environmentally friendly manufacturing processes. Ms. Dollar has 18 years of experience in sales and marketing within the paper industry. She has worked for several Paper Corporation of America merchant houses, most recently Conservatree Paper Company, where she did policy research on recycled paper issues. She also worked as Sales Manager of Silver Leaf Paper Corporation, a recycled paper manufacturer. Ms. Dollar has testified on paper issues before the Senate Subcommittee on Energy Regulation and Conservation and the Joint Committee on Printing, and frequently consults with congressional and EPA staff on paper issues. She has been active with several paper recycling groups, including the Recycling Advisory Council, ASTM, and the Environmental Action Paper Definitions Working Group; she also works closely with Greenpeace, NRCD, and EDF.

Dick Erickson

Vice President, Environmental and Technology
Weyerhaeuser Company
Tacoma, Washington

Dick Erickson has worked for the Weyerhaeuser Company for over 21 years, serving in a variety of positions including Research Scientist, Technical Service Manager for Market Pulp, Pulp Mill Superintendent, Assistant to Senior Vice President for Operations, Mill Manager, and Vice President for Manufacturing and Technology. Dr. Erikson earned a B.S. in Chemical Engineering from Washington State University and a Ph.D. from the Institute of Paper Chemistry in 1969.

Linda J. Fisher

Assistant Administrator, Office of Prevention, Pesticides and Toxic Substances
U.S. Environmental Protection Agency
Washington, D.C.

Linda J. Fisher is EPA's Assistant Administrator for Prevention, Pesticides and Toxic Substances. In this position, she oversees the Agency's pollution prevention, pesticide and toxic programs. She previously served as EPA's Assistant Administrator of Policy, Planning and Evaluation, where she had primary responsibility for developing the Agency's position on global climate change and establishing the Office of Pollution Prevention. Ms. Fisher first joined the Agency in 1983 as Special Assistant to the Assistant Administrator for Solid Waste and Emergency Response. From 1985 to 1988, she served as Chief of Staff for Administrator Lee M. Thomas. She was the principal policy liaison with Congress and the White House during the rewriting of the Superfund law in 1986. Prior to joining EPA, Ms. Fisher worked as a legislative assistant to Ohio Congressmen

Clarence J. Brown and Ralph Regula. She also served as Associate Staff Member to the House Appropriations Committee. Ms. Fisher received her undergraduate degree from Miami University of Ohio, and completed an M.B.A. in Business Administration at George Washington University. She received her J.D. from Ohio State University's College of Law.

Bruce I. Fleming

Senior Research Advisor
Boise Cascade
Portland, Oregon

Bruce I. Fleming recently joined Boise Cascade as Senior Research Advisor for the Portland, Oregon, laboratory. Until recently, he was with the Pulp and Paper Research Institute of Canada (Paprican), where he was Director of Paprican's Chemical Pulping and Bleaching Division. Along with four coauthors, he was awarded the Weldon Medal by the Canadian Pulp and Paper Association in 1990 for a paper on dioxin abatement; he was recently elected a Technical Association of the Pulp and Paper Industry (TAPPI) Fellow.

Jens Folke

Director
European Environmental Research Group (MFG)
Allerod, Denmark

A native of Denmark, Jens Folke is currently Director, Environmental Research Group Ltd., in Allerod. Dr. Folke specializes in low-waste technology, environmental impact assessment, resource management, and wastewater treatment technologies, especially in regard to the pulp and paper industry. Clients include the Danish National Agency for Environmental Protection, the Nordic Council of Ministers, the EC-Commission, the Ministry of Environments in Ontario and Alberta, and the U.S. Environmental Protection Agency. During 1990 Dr. Folke was a visiting scholar on the Faculty of Environmental Engineering at the University of Washington, Seattle. He has traveled and worked internationally in Canada, Cuba, Egypt, Finland, Great Britain, the Far East, Eastern Europe, and the United States. Dr. Folke is active in professional associations, including the Technical Association of the Pulp and Paper Industry (TAPPI), where he received a certificate for the "Best Technical Paper" in the General Category for the 1991 TAPPI Environmental Conference. He also belongs to the International Association on Water Pollution Research and Control (IAWPRC), and the Danish Society of Professional Engineers (DIF). In 1984 he won the Hede-Nielson Prize for research on environmental impact assessment of industrial effluents. Dr. Folke received a M.S. in Organic Chemistry and Biochemistry at the University of Copenhagen, Denmark. He earned a Ph.D. in Environmental Chemistry at the Technical University of Chalmers and the University of Gothenburg, Sweden.

Mark Greenwood

Director, Office of Pollution Prevention and Toxics
U.S. Environmental Protection Agency
Washington, D.C.

As Director for the Office of Pollution Prevention and Toxics, Mark Greenwood is responsible for implementing the Toxic Substances Control Act, the Asbestos School Hazard Abatement Act, the Asbestos Hazard Emergency Response Act, the Pollution Prevention Act, and certain sections of the Comprehensive Environmental Response, Compensation, and Liability Act and the Community Right-to-Know Act. As Director, Mr. Greenwood has led initiatives such as the 33/50 Program and Design for the Environment. He is also charged with the maintenance and dissemination of the Toxics Release Inventory. In 1978 he joined EPA's Office of General Counsel, for whom he worked on a variety of issues under the Clean Water Act and on solid waste legislation. He was named the first Assistant General Counsel for RCRA in 1983, and in 1987 he assumed the duties of Assistant General Counsel for the Superfund Program. In 1988, he became the Associate General Counsel for the Office of Pesticides and Toxic Substances. Mr. Greenwood is a graduate of the University of Michigan Law School. He also received a graduate degree in Public Policy Studies from the same institution.

Ann Hillyer

Barrister and Solicitor
West Coast Environmental Law Association
Vancouver, B.C., Canada

Ann Hillyer is a staff lawyer with West Coast Environmental Law Association, a nonprofit public interest organization in Vancouver, British Columbia, providing legal advice and counsel to individuals and organizations with environmental problems. Ms. Hillyer has practiced law in British Columbia since 1986 and has worked with the West Coast Environmental Law Association since 1989. Currently Ms. Hillyer is working on a number of environmental issues, including pollution from pulp mills and problems related to atmospheric change. She represents individuals and 54 organizations, with over 250,000 members, who are concerned about pollution from pulp and paper mills in British Columbia.

Harold L. Hintz

Technical Assistant to Vice President and Corporate Research Director
Westvaco Corporation
New York, New York

Harold L. Hintz joined Westvaco in 1966 and has served as Technical Assistant to the Vice President and Corporate Research Director since 1981. Over the course of his career he has held a variety of positions, including Research Scientist, Technical Director, and Group Leader, Charleston Research. Dr. Hintz received a B.A. in Chemistry from Wesleyan University and an M.S. and Ph.D. in Paper Science from The Institute of Paper Science and Technology. His thesis won the Westbrook Steele Gold Medal.

Donald W. Hopkins

Vice President and General Manager
Hearst Enterprises Division,
The Hearst Corporation
New York, New York

As Vice President and General Manager of the Hearst Enterprise Division, The Hearst Corporation, Donald W.

Hopkins is responsible for paper supply and quality to Hearst newspapers, magazines, and books. Prior to assuming his present position, Mr. Hopkins was with Hearst's Pejepscot Paper Division, where he was responsible for operations, sales and marketing, and woodlands. During the 1960s and 1970s, Mr. Hopkins worked in various accounting and administrative positions at Oxford Paper Company and Boise Cascade Corporation. He is active in numerous professional associations, including the Technical Association for the Pulp and Paper Industry (TAPPI), PIMA, NPMA, and MPA, and is a past President of the Paper Industry Information Office, State of Maine. He attended Northeastern Business College in Accounting/Business Administration.

Virgil K. Horton, Jr.

Vice President, Paper Group
American Paper Institute
New York, New York

Virgil K. Horton, Jr., joined the American Paper Institute (API) in January 1990 as Vice President of the Paper Group. He is responsible for the group's four divisions and represents the paper segment of the industry to public, Federal, and State regulators, customer associations, and ad hoc groups. Mr. Horton worked for Westvaco Corporation for 25 years in senior sales and marketing management positions before joining API. He has had extensive experience in electronic communication, specifically bar coding and electronic data exchange. Active in professional groups, Mr. Horton was a founding member of the Interassociation Council on Paper Waste Management, which serves as a forum for members of the print communications industry to share information and educate the public about recycling. He has served on the board of the Graphic Communications Association and currently serves on the United States Postal Service's Mailer's Technical Advisory Committee. Mr. Horton received a B.B.A. from Georgia State University in Marketing/Management, and holds an M.B.A. in Marketing/Finance from St. Louis University.

Clifford T. "Kip" Howlett, Jr.

Vice President, Government Affairs
Georgia-Pacific Corporation
Atlanta, Georgia

As Georgia-Pacific's Vice President for Government Affairs, C. T. "Kip" Howlett, Jr., is responsible for the development and implementation of corporate policy. Mr. Howlett has published numerous articles and books on such diverse subjects as the production and utilization of biomass energy, federal timber land-use planning policies, and the economic effects of land-use controls. His publications also include several papers on the regulation of toxic chemicals, including formaldehyde. Mr. Howlett currently serves as Chairman of the Coalition for Fair Lumber Imports and the American Paper Institute's (API) Health Committee. He was previously Chairman of the National Association of Manufacturers OSHA Policy Committee, the National Forest Products Associations Inter-industry Wood Dust Committee, and several API committees. Mr. Howlett is a graduate of the Johns Hopkins University in Baltimore and Willamette University College of Law, Salem, Oregon.

Lubomir Jurasek

Head, Biological Chemistry Section
Pulp and Paper Research Institute of Canada
St. Claire, Quebec, Canada

Lubo Jurasek joined the Pulp and Paper Institute of Canada (Paprican) in 1975, and is now Head, Biological Chemistry Section, Process Chemistry Division. His research interests are in mechanisms of biological modification of lignocellulosic materials. Before joining Paprican, Dr. Jurasek was on the staff of the Forest Products Research Institute, Bratislava, Czechoslovakia (1954-68); he was also a National Research Council of Canada Postdoctoral Fellow (1964-66) and a Research Associate and Lecturer at the University of Alberts (1968-74). Dr. Jurasek is a member of the BIOFOR Steering Committee, the Society for Industrial Microbiology, the American Chemical Society, and the American Society for Microbiology. Dr. Jurasek received an R.N. Dr. and a C.Sc. from the University of Brno, Czechoslovakia.

Russell E. Kross

Vice President, Human and Environmental Protection
The Mead Corporation
Dayton, Ohio

Russell E. Kross has been with the Mead Corporation for 24 years. He has directed Mead's corporate programs for employee health and safety, environmental control, and product safety since the early 1970s. He was named an officer and Vice President of Mead in 1990. Prior to joining Mead, Mr. Kross spent four years at the Iowa Health Department. He holds an M.S. in Environmental Engineering from the University of Iowa.

Norman Liebergott

Special Consultant
DuPont Canada Inc.
Laval, Quebec, Canada

Norman Liebergott is a Consultant to DuPont Canada, Inc. He is also an adjunct professor in the Department of Chemical Engineering at McGill University. Dr. Liebergott was formerly a Senior Scientist at the Pulp and Paper Research Institute of Canada (Paprican). His research in the area of pulp bleaching processes and environmental control has earned 26 patents, and he has published over 90 scientific articles. He has reported his work at over 100 scientific meetings and been invited to numerous plants in Canada and the United States to provide technical assistance. Dr. Liebergott has won two Weldon medals from the Canadian Pulp and Paper Association and Best Paper Awards from the Environmental Conferences of the Technical Associations of Pulp and Paper Industry and the Pulp Manufacturers. He also received a C.F.C. Ritter Prize and Paprican's Presidential Citation for his work. Dr. Liebergott was named a Technical Association of the Pulp and Paper Industry (TAPPI) Fellow in 1991. Dr. Liebergott received a diploma in textile chemistry, an A.B.Sc. Degree in mathematics, and a D.Sc. in Chemistry from Sir George Williams University.

Lars-Åke Lindström
Vice President, Research and Development
Sunds Defibrator Industries AB
Sundsvall, Sweden
Lars-Åke Lindström joined Sunds Defibrator AB in 1984 and worked in several management positions before becoming Vice President for Research and Development in 1986. Prior to joining Sunds, Dr. Lindström was Manager of Pulp Bleaching at SCA Research. Dr. Lindström earned both an M.S. and Ph.D. in Chemical Engineering from Chalmers University of Technology, Sweden.

Neil McCubbin
President
N. McCubbin Consultants, Inc.
Foster, Quebec, Canada
Since immigrating to Canada in 1965, Neil McCubbin has worked almost entirely in the pulp and paper industry, initially in mills and later as a consultant in North America and overseas. In earlier years his work involved detailed engineering for mill installations, including one of the first effluent treatment systems installed in a Canadian pulp mill, while more recent work has concentrated on process aspects of environmental protection systems in the industry. He has been retained by regulatory authorities as well as industry and industrial associations. Mr. McCubbin is author of over one hundred technical publications.

Thomas J. McDonough
Professor of Engineering and Group Leader for Pulping and Bleaching
The Institute of Paper Science and Technology
Atlanta, Georgia
Thomas J. McDonough is Professor of Engineering and Group Leader for Pulping and Bleaching at The Institute of Paper Science and Technology (IPST) in Atlanta, Georgia. His responsibilities include the direction of academic and industrial research in the science and technology of pulp manufacture. Mr. McDonough has a record of extensive professional involvement and numerous publications in areas related to the practice and fundamentals of pulp bleaching, pulping, and lignin reactions. Before joining IPST, he held research positions at Canadian International Paper Company and the Canadian Industries Limited. He earned his Ph.D. in Chemical Engineering at the University of Toronto.

David Mager
Director of Environmental Standards
Green Seal
Washington, D.C.
David Mager is Director of Environmental Standards at Green Seal, an independent, nonprofit organization that encourages the manufacture and purchase of environmentally responsible products through standard setting and product certification. Mr. Mager has a long history of expertise in product design and process, including numerous patents and inventions. Prior to joining Green Seal, Mr. Mager wrote Growing Green Plants: the Environmental Component of Manufacturing Process and Product Development, which was presented to General Motors, IBM, General Electric, McDonald's, Nestle-Carnation, Coca Cola, Hallmark, Anheuser-Busch and Citibank, among others, to help these companies design environmentally superior products and redesign company operations to incorporate environmental processes. He was one of five U.S. delegates to the International Standards Organization and one of 50 experts asked to participate in the Society of Environmental Toxicologists and Chemists' Data Quality Workshop focused on advancing the science of Life Cycle Analysis. Mr. Mager also wrote the criteria for and was a judge in Inc. magazine's Environmental Design Award.

Steve Moldenius
Technical Director and Manager, Research and Development
Södra Cell
Morrum, Sweden
Steve Moldenius is Technical Director and Manager, Research and Development, at Södra Cell, Morrum, Sweden, where he is currently working to develop chlorine-free kraft pulps. Dr. Moldenius previously worked for Sunds Defibrator and STFI. He holds a doctorate in Cellulose and Paper Technology from the Royal Institute of Technology, Stockholm, Sweden.

Donald G. Monefeldt
Manager, Supply Products Marketing
Xerox
Webster, New York
Donald Monefeldt has worked for Xerox for 29 years and is currently Manager of Supply Products Marketing. During his career at Xerox, he has worked in supplies manufacturing, development, and program management; machine product planning and program management; and supplies marketing. Mr. Monefeldt has pursued several environmental efforts on behalf of Xerox, including initiating the National Office Paper Recycling Project, which is chaired by the U.S. Conference of Mayors. In addition, he conceived and implemented the Eco White corrugated container (outer ply made from repulped waste white office paper) for Xerox Supply Products and the Mixed Waste Paper Brown container for Xerox parts. He also developed an educational brochure about paper recycling for Xerox customers and initiated a project to use recycled plastic in Xerox consumables packaging.

Michael J. O'Rourke
Catalog Manager, IKEA North America
IKEA U.S., Inc.
Plymouth Common, Pennsylvania
Michael J. O'Rourke, Catalog Manager for IKEA North America (the world's largest furnishings retailer) since 1989, formerly worked in Sweden, where he accumulated experience in many areas of the publishing business, from catalog production to periodicals. Mr. O'Rourke received a degree in Urban Affairs from Virginia Polytechnical Institute and State University.

Richard B. Phillips
Staff Vice President and Director of Process Technology
International Paper
Mobile, Alabama

Richard B. Phillips is Staff Vice President and Director of Process Technology at International Paper. His dual responsibilities include corporate environmental affairs and development and application of process technology for the company's pulp and paper manufacturing facilities worldwide. Dr. Phillips joined International Paper in 1971 and has held a variety of technical and engineering positions, including Manager of Chemical Process Technology, Manager of Manufacturing Technical Service for the pulp and paper business groups, and Associate Director of Process Innovation. He has authored over 20 publications and holds five U.S. patents on oxygen and ozone bleaching. A graduate of North Carolina State University with a Ph.D. in Chemical Engineering, Dr. Phillips also attended the Centre Technique du Papier, University of Grenoble, France, for postgraduate research.

Martha G. Prothro
Deputy Assistant Administrator, Office of Water
U.S. Environmental Protection Agency
Washington, D.C.

Martha Prothro is Deputy Assistant Administrator for Water at the U.S. Environmental Protection Agency (EPA). In this capacity, she serves as the senior career advisor to the Assistant Administrator and is responsible for the national water quality management program, which includes water quality criteria and standards, drinking water criteria and standards, NPDES permits for point sources of water pollution, nonpoint source controls, the State Revolving Fund program for constructing municipal wastewater treatment plans, and shared responsibility with the U.S. Army Corps of Engineers for regulating wetlands and the disposal of 250 million cubic yards of dredged material each year. A career public servant with over 25 years of government service, Ms. Prothro joined EPA in 1973 as an enforcement attorney in the air pollution control program and eventually rose through the ranks to direct the Noise and Radiation Enforcement Division. In 1981, she moved to the Water Division, where she was responsible for the NPDES Permits Program and the national pretreatment program. In 1988, she was named Director of the Office of Water Regulations and Standards. In April 1991, she moved to her current position. Ms. Prothro has a B.A. degree from the University of North Carolina and a J.D. from George Washington University's National Law Center. She has received numerous awards, including the Presidential award for meritorious service as a senior executive.

Margaret Rainey
Greenpeace Paper Campaign
Göteborg, Sweden

Margaret Rainey has been working with environmental problems related to paper production and consumption since 1986, when she started working for Greenpeace. She is the Swedish representative of the Greenpeace International Paper Campaign working to end chlorine-bleaching, increase recycling, reduce overconsumption of paper and protect forest biodiversity. She has spoken on a wide range of environmental aspects of the pulp and paper industry at international conferences arranged by the European Community, the United Nations, the pulp and paper industry, etc. Her education includes studies in natural science ecology and human ecology.

Douglas Reeve
Director, Pulp and Paper Centre
University of Toronto
Toronto, Ontario, Canada

Douglas Reeve is Professor of Chemical Engineering and Applied Chemistry, and Director of the Pulp and Paper Centre at the University of Toronto. Dr. Reeve has long been a consultant in new process technology for the pulp and paper industry; he is widely known for his many publications and patents on the closed-cycle bleached Kraft pulp mill, pulp bleaching and the environment, and kraft recovery boiler fireside chemistry. Dr. Reeve has been very active in the technical section of the Canadian Pulp and Paper Association and Technical Association of the Pulp and Paper Industry (TAPPI), where he is a Fellow and a recipient of the 1988 TAPPI Pulping Division Medal. Dr. Reeve, a member of both the TAPPI and CPPA Bleaching Committees, is Chairman of the TAPPI Bleach Plant Operations Short Course, the TAPPI Kraft Recovery Operations Short Course and Leader of the CPPA Kraft Pulp Bleaching Course. Dr. Reeve earned a B.S. (Honors Chemistry) from the University of British Columbia and a Ph.D. in Chemical Engineering at the University of Toronto.

David J. Refkin
Director of Environmental Affairs and Assistant Director of Paper Purchasing
The Time Inc. Magazine Company
New York, New York

David J. serves as Time Inc.'s Director of Environmental Affairs and Assistant Director of Paper Purchasing. In his current position, Mr. Refkin has two major areas of responsibility. He is responsible for environmental and recycling activities for the company. He also plays a major role in the purchasing of all the paper stock for the company's magazine. Mr. Refkin is a member of the Recycling Advisory Council's Paper Committee. In addition, he is a member of the Magazine Publishers of America Waste Reduction Task Force and the Print Communications Industry Council on Waste Management. Following a short career in public accounting, Mr. Refkin first joined Time Inc. in 1982 in Corporate Finance. Mr. Refkin joined the Magazine, Manufacturing and Distribution division in 1986 as its Business Manager. He became the Assistant Director of Paper Purchasing in May 1989 and added the title of Director of Environmental Affairs in May 1992. A native of New York City, Mr. Refkin, a C.P.A., has a B.S. degree in Accounting from the State University of New York at Albany and a M.B.A. degree from Iona College.

John S. Seitz
Director, Office of Air Quality Planning and Standards
Office of Air and Programs
U.S. Environmental Protection Agency
Washington, D.C.

Since 1990, John Seitz has been responsible for the overall policy, management, engineering, and scientific direction of the U.S. Environmental Protection Agency's (EPA's) Office of Air Quality Planning and Standards. He joined EPA in 1971 as a Case Development Officer and has also served as Chief, Regional Operations, Office of Enforcement, where he was responsible for directing and managing EPA's regional implementation of the Toxic Substances Control Act and the Resource Conservation and Recovery Act. In 1980, Mr. Seitz was named Chief, Compliance Monitoring Unit, Office of Pesticides, where he managed and directed all operational aspects of implementing compliance monitoring programs. From 1984 to 1987, he was Chief Executive Officer, Office of Compliance Monitoring, Office of Pesticides and Toxic Substances. In this capacity, Mr. Seitz managed and helped implement EPA's pesticides and toxic substances compliance/enforcement programs. In 1987, he became Director, Stationary Source Compliance Division, where he focused on the overall implementation of the stationary compliance provisions of the Clean Air Act. Mr. Seitz has a B.S. degree from the University of Delaware.

Ladd T. Seton
Export Sales
Fraser Paper, Limited
Stamford, Connecticut

Ladd T. Seton has held a variety of technical customer service and marketing positions in the paper industry for over 30 years. He recently joined Fraser Paper, Limited, as General Manager, Market Pulp, with responsibility for worldwide sales of sulphite market pulp. He is now heading the export sales effort. Before joining Fraser Paper, Mr. Seton worked for other producers of market pulp, including International Paper Co., Weyerhaeuser, and Louisiana Pacific Company. His experience encompasses manufacturing, customer technical services, and marketing. Mr. Seton is a graduate of Oklahoma State University with a B.S. in Chemical Engineering.

Howard Sproull III
President
ECO Paper Source
Chicago, Illinois

Howard E. Sproull III, is a consultant for paper manufacturers, and markets chlorine-free papers across the United States. He provides consulting services to both domestic and offshore manufacturers, developing product introduction, and marketing strategies for supplying chlorine-free papers. Customers currently utilizing chlorine-free papers from ECO Paper Source are end-users, corporations, printers, and merchants. Mr. Sproull previously worked in marketing and sales with a domestic coated paper manufacturer and a regional paper merchant. He completed his B.S. in Wood and Paper Science at North Carolina State University, and received an M.B.A. in International Business from DePaul University.

Richard E. Storat
Vice President, Economic & Financial Services
American Paper Institute
New York, New York

Richard E. Storat is Vice President, Economic and Financial Services of the American Paper Institute (API), the national trade association serving the pulp, paper, and paperboard industry. He joined the Institute in 1987. Prior to joining API, Mr. Storat served in a series of corporate management positions, including strategic planning, energy policy, and engineering assignments. In Washington, D.C., in the early 1980s, Mr. Storat served as the key staff assistant for synthetic fuels on the Fossil and Synthetic Fuels Subcommittee of the House Energy and Commerce Committee. Mr. Storat concluded ten years of service in the U.S. Army as an Assistant Professor of Physics at the U.S. Military Academy, West Point. He is a member of several professional associations, including the National Association of Business Economists. He earned his B.S. at West Point, an M.S. at the Massachusetts Institute of Technology, and an M.B.A. with an emphasis on economics at Lehigh University.

C. Bertil Stromberg
Director, Research and Development Laboratory
Kamyr, Inc.
Glens Falls, New York

Mr. Stromberg, a native of Sweden, joined Kamyr in 1979 as a Process Engineer. Since then he has held a number of positions at the Glens Falls, New York, laboratory, and became Director of the lab in 1990. Prior to joining Kamyr, Mr. Stromberg was an Engineer in Karlstad, Sweden. He is the holder of two patents, one for reducing contamination in pulp processing, and the other on washing for low bleach chemical consumption; three additional patents are pending. In addition, Mr. Stromberg has published scholarly articles. He is a member of the Technical Association for the Pulp and Paper Industry (TAPPI), CPPA, the Swedish Pulp and Paper Engineers Association, AIChE, and Swedish Chemical Engineers Association. Mr. Stromberg received his M.S. in Chemical Engineering, Pulp and Paper Specialization, from the Royal Institute of Technology, Stockholm.

Kit Taylor
Vice President Manufacturing
Times Mirror Magazines
New York, New York

As Vice President of Manufacturing for Times Mirror Magazines, Kit Taylor is the manufacturing and distribution supplier liaison for Times Mirror Magazines' ten national special-interest magazines, including *Field and Stream*, *Popular Mechanic*, and *Outdoor Life*, as well as for the magazines published by Sports Marketing Group, the company's custom publishing division. Ms. Taylor's 26-person department handles the purchasing of all paper and coordinates prepress and printing operations. She also supervises the company's Creative Service Department, which produces all corporate promotional materials. Before joining Times Mirror Magazines in 1987, Ms. Taylor was at Esquire Magazine Group, Inc., where she was responsible for the print, buying, manufacturing, and distribution of five divisions, includ-

ing *Esquire* and *New York World*; the Esquire Health & Fitness Clinic; a wall media publication; and Club Pack, a sampling program. Ms. Taylor began her career in magazine publishing with the *Texas Monthly* in 1973. She joined the *Austin Sun* as production coordinator in 1975 and later became production manager of *"D" Magazine* and *Texas Homes*. She relocated to New York in 1981. Ms. Taylor received a B.S. from the University of Texas.

Roger Telschow

President
Ecoprint
Silver Spring, Maryland

Roger Telschow is President and founder of Ecoprint, a Silver Spring, Maryland, sheetfed printing company. Ecoprint has extensive experience in printing on recycled papers, using nonpetroleum, vegetable oil-based inks, and "environment-friendly" pressroom chemicals. A recognized innovator in the area of environmental "super-compliance," Mr. Telschow also speaks on the subject of "total quality," as his company has won two awards for excellence in quality and service. Ecoprint, which is dedicated to environmental and product quality, is currently working on the reformulation of printing inks to remove heavy metal-based pigments, funded in part by an EPA pollution prevention grant.

Luigi Terziotti

Vice President, Pulp and Paper Operations
Parsons & Whittemore
Claiborne, Alabama

A native of Italy, Luigi Terziotti is presently Corporate Vice President, Pulp and Paper Operations, Parsons & Whittemore. He is also responsible for the operation of all manufacturing divisions, including the St. Anne Pulp Company, Nackawic, New Brunswick, Canada, as well as the Alabama River Newsprint Company and the Alabama Pine Company, which are located at Claiborne alongside the Alabama River Pulp. Dr. Terziotti joined the Black Clawson Company—then a Parsons & Whittemore affiliate—as a Project Engineer in 1961, working first in London, then in Middletown, Ohio. In 1973, he was transferred to Parsons & Whittemore's main office in New York; in 1977, he moved to the Claiborne plant as Project Manager, and subsequently became Executive Vice President/General Manager. Dr. Terziotti serves on the boards of Auburn University's Pulp and Paper Foundation and the Alabama Southern Community College Foundation. He received a Doctor of Industrial Chemistry degree from Bologna University.

William H. Trice

Executive Vice President
Union Camp Corporation
Wayne, New Jersey

As Executive Vice President of Union Camp Corporation, Dr. Trice is responsible for research and development, environmental affairs, and profit and loss responsibility for the world-wide chemical business of Union Camp. He has had extensive experience in technology development in the pulp and paper industry, having worked as a Research Scientist Group Leader and Section Leader in research and development and having held senior technical management responsibilities at the division and corporate levels. Dr. Trice is active in education and research organizations of the pulp and paper industry and is currently a member of the American Paper Institute's Environmental Steering Committee. He completed his undergraduate work at the College of Environmental Science and Forestry at Syracuse University, and received his M.S. and Ph.D. from the Institute of Paper Science and Technology.

Mary Ellen Weber

Director, Economics, Exposure and Technology Division
Office of Pollution Prevention and Toxics
U.S. Environmental Protection Agency
Washington, D.C

Mary Ellen Weber is Director of the Economics, Exposure and Technology Division (EETD) in the Office of Toxic Substances at the U.S. Environmental Protection Agency. EETD is responsible for all engineering, industrial chemistry, environmental exposure, and economic analyses of toxic substances. In the 1980s, Dr. Weber cofounded a computer software company specializing in designing and marketing databases for occupational and employee medical records. Prior to that, Dr. Weber was the Director of the Office of Regulatory Analysis at the United States Department of Labor — Occupational Safety and Health Administration (OSHA). In this position she directed engineering and economic analyses for all health and safety regulations. Prior to joining government, Dr. Weber worked as a Country Economist at the World Bank and at the International Research and Technology Corporation (IR&T). At IR&T, she conducted a variety of regulatory impact studies for EPA, the Department of Energy, and the private sector, focusing on the impact of various public policies on the environment. Dr. Weber has a B.A. in Economics from Dominican College and a Ph.D. in Economics from the University of Utah. She has done postgraduate work at Stanford University, the University of Chile, and the Universidad Nacional Autonoma de Mexico. She completed her international education by serving in Chile on a Foreign Area Fellowship under the auspices of the Social Science Research Council and by working as an Production Assistant at CBS Television News. On her return to the United States, Dr. Weber joined the faculty of Smith College, where she taught economics.

Dee Williams

Toxics Reduction Specialist
Washington State Department of Ecology, Waste Reduction Program
Olympia, Washington

Dee Williams is a Toxics Reduction Specialist with the Washington State Department of Ecology, Office of Waste Reduction, Recycling and Litter Control (WRRLC). She provides technical assistance to businesses for developing and implementing pollution prevention programs focusing on hazardous substance use and waste reduction. Ms. Williams has worked with various pulp and paper mills in Washington State and with EPA

Region 10 and a local pulp mill to compile a "Model Pollution Prevention Plan for the Pulp and Paper Industry." She has participated in regional meetings of the National Council of the Pulp and Paper Industry for Air and Stream Improvement, the Northwest Pulp and Paper Association, and the Washington Pulp and Paper Foundation.

Michael D. Witt

Chief, Industrial Wastewater Section
Wisconsin Department of Natural Resource
Madison, Wisconsin

As Section Chief for Industrial Wastewater at the Wisconsin Department of Natural Resources, Michael D. Witt coordinates and supervises the issuance of NPDES permits to 1,500 industries in Wisconsin, including discharges to surface and groundwaters from pulp and paper mills. He also supervises the animal waste regulatory program, oversees plans for treatment systems for industries, and develops administrative codes in response to statutory requirements. Mr. Witt joined the Wisconsin environmental agency in 1974, and has coordinated areawide water quality management plans and developed training courses on U.S. EPA municipal facility plans. He has also designed programs dealing with wasteload allocation of pulp and paper mill discharges along the Fox and Wisconsin Rivers. Mr. Witt received a B.S. in Civil Engineering from the University of Wisconsin-Madison, and an M.S. in Civil and Environmental Engineering, also from the University of Wisconsin-Madison.

Peter E. Wrist

President and Chief Executive Officer
Pulp and Paper Research Institute of Canada
Pointe-Claire, Quebec, Canada

Peter E. Wrist joined the Pulp and Paper Research Institute of Canada (Paprican) in 1983 and was elected Chief Executive Officer in 1986. Before joining Paprican, he was Vice President of Mead Corporation, where he had held a number of management and research positions from 1956 to 1983. From 1949 to 1952, he worked as a Research Physicist for the British Paper and Board Makers Research Association, and held a similar position with the Quebec North Shore Paper Company from 1952 to 1956. Mr. Wrist is a pioneer in papermaking research and development. His work in head box design, forming fabrics, and drainage on the fourdrinier paper machine helped to develop the new technology responsible for today's significantly increased production rates. He also played a key leadership role on behalf of the pulp and paper industry in obtaining responsible environmental legislation in the United States. Mr. Wrist is a member of the Technical Section, CPPA; the New York Academy of Sciences; and the Marcus Wallenberg Foundation Selection Committee. He is also a past President of the Technical Association of the Pulp and Paper Industry (TAPPI), and past Chairman of NCASI and The Institute of Paper Chemistry's Research Advisory Committee. For his professional achievements, Mr. Wrist has received the Canadian Pulp and Paper Association Howard Smith and Weldon Gold Medals, and the TAPPI Engineering Division and Gold Medal Awards. He was designated a TAPPI Fellow in 1974. Mr. Wrist received a B.A. in Physics and an M.A. in Mathematics from Cambridge University, England, and a M.S. degree in crystallography from London University, Birbeck College. He also attended the Advanced Management Program of the Harvard Business School.

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Conference Note

One of the objectives of the Symposium was to explore the availability and acceptability of chlorine-free and unrebleached recycled paper products. The EPA had planned to print these Proceedings on 100 percent postconsumer unrebleached paper to give the readers an opportunity to observe one use of an alternative paper. The Joint Committee on Printing (JCP) of the U.S. Congress specifies the products and services the Government Printing Office may provide. (Federal government publications must be printed in federal printing facilities.)

A price competitive U.S. manufacturer of 100% postconsumer unrebleached paper was identified for the JCP. The JCP was unwilling to add this paper to its approved list of paper. The JCP noted that the approved paper list currently contains recycled (chlorine-bleached) paper and objected to the fact that there was at that time only one U.S. manufacturer of the paper type EPA had requested.

Recently, JCP has received requests for permission to use chlorine-free and unrebleached recycled paper from a number of sources and is reviewing the policy forbidding use of these alternative papers in federal printing facilities.