EFFLUENT MINIMIZATION—A LITTLE WATER GOES A LONG WAY

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THE TREND IN EFFLUENT MINIMIZATION AND AN OVERVIEW OF THE CONVENTIONAL APPROACHES FOR EFFLUENT REDUCTION ARE PRESENTED. THE AUTHOR ALSO GIVES A BRIEF INTRODUCTION TO THE RECENTLY DEVELOPED TECHNOLOGIES.

AN EFFLUENT-FREE PULP MILL IS THE DREAM OF THE environmentalists and of many engineers and scientists. Research toward this goal has been ongoing for over three decades. During the last few years, the effluent-free pulp mill has been a hot topic in the technical conferences and industry trade and research journals. Effluent from the pulp and paper industry has received a great deal of public attention in recent years, and water contamination is quite visible. Some states have begun to discuss water taxation based on usage. In the future, high water usage and effluent quantities may have significant financial implications for the manufacturing facility.

This article presents the trend in effluent minimization and an overview of the conventional approaches for effluent reduction. A brief introduction to the recently developed technologies and those under development is also presented.

WATER CONSUMPTION IN THE PULP AND PAPER MILLS

The pulp and paper industry in the United States and many other countries has reduced the water consumption per ton of product significantly during the last 20–30 years. The National Council of the Pulp and Paper Industry for Air and Stream Improvement (NCASI) conducted the water use surveys in 1975, 1985, and 1988. The water consumption per ton of product was reduced by 34.5% between 1975 and 1988.

Mean water consumption for the U.S. pulp and paper industry from the NCASI surveys and other published information is presented in Fig. 1.

Most recent data on water consumption in the pulp and paper industry was presented by Bryant *et al. (1)* and is based on the FisherPulp™ database. Table I presents the information from this database for various categories of pulp and paper mills. The FisherPulp™ database is maintained by Fisher International of South Norwalk, CT. Data for more than 650 U.S. and Canadian mills was available in the database in 1996.

This article focuses on the water use and effluent generation in the bleached kraft mills. Figure 2 presents the effluent quantities from some bleached kraft mills based on the published information and BE&K file data. A sample of fresh water consumption in the bleached kraft pulp mills is presented in Table II *(2).* This table presents the water consumption for the older mills (10–20 years), for newer mills (last 10 years), and for the mills currently being designed.

EXAMPLES OF THE LOW-EFFLUENT MILLS

Many bleached kraft pulp mills worldwide are making efforts to adopt "closed cycle" technology and to minimize the effluent. These include the following:

- Riocell and Bahia Sul: Brazil
- Alberta-Pacific: Canada
- Metsa-Rauma: Finland
- Selinga Pulp and Paper Co.: Russia
- SAPPI (Ngodwana): South Africa
- MoDo, SCA Pulp, Sodracell, and Stora Billerud: Sweden
- Phoenix Pulp and Paper and Advance Agro: Thailand
- Louisiana-Pacific Samoa, Champion, International Paper, Union Camp, and Weyerhaeuser: United States.

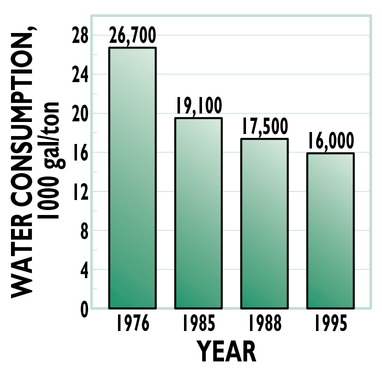
EFFLUENT REDUCTION IN THE EXISTING MILLS

Mills have different reasons for reducing their water consumption and effluent generation. Some reasons are as follows:

		STATISTICS, 1000 gal/ton					
Mill type	Mills	Mean	±*	Median	Wt. mean	High	Low
Integrated bleached	104	23.4	1.8	22.9	21.6	48.2	8.9
Integrated unbleached	44	11.4	1.4	10.1	10.5	24.6	3.4
Paper mill > 100 tons/day	218	8.0	1.8	3.6	8.0	145.2	0.1
Bleached market kraft pulp	32	22.4	2.2	23.0	22.0	34.0	11.3
Newsprint (mechanical pulp)	40	10.4	1.5	9.7	9.9	27.3	3.3
Corrugating medium (NSSC)	21	6.4	2.1	4.5	6.6	21.1	0.7
Newsprint (mech. and high-yield)	17	19.7	6.7	15.5	19.7	71.1	8.9
Deinked secondary fibers	36	9.7	2.1	9.5	10.5	21.9	0.1
Dissolving pulp	8	51.0	15.2	41.4	44.5	84.4	25.3
Paper mill < 100 tons/day	135	18.0	3.0	12.0	14.1	87.5	0.3
Market sulfite, BCTMP, and other	9	18.0	13.4	4.5	16.2	49.5	0.3

*95% confidence level of the calculated mean

I. Summary data of water consumption by mill type (1)



1. Water consumption in the U.S. pulp and paper industry

- Regulatory compliance
- A production increase without increasing total water intake or effluent discharge
- Economics. The closure of mill water system typically reduces the steam use for water and white water heating. On a site-specific basis, it can also lower the chemical and fiber losses and effluent treatment costs.
- Market forces.

A reduction in water usage and effluent in an existing mill involves the following major steps:

- Develop a good water balance for the current operation
- Compare the water usage for various process areas with good examples.
- Identify areas with high potential for water reduction.
- Identify opportunities in process areas for reuse/recycle.
- Define the process and equipment modifications or additions needed.
- Develop an order-of-magnitude cost estimate for various projects.
- Prepare a cost–benefit analysis, and rank the projects based on cost effectiveness.
- Select the projects that will meet the target of water usage reduction and/or effluent reduction.
- Finalize an implementation plan and schedule for the selected projects.

The opportunities for effluent reduction are generally very site-specific and depend on the current performance of the mill with respect to the generated effluent volume. Obviously, the mills at the higher end of the spectrum of effluent quantity (20,000 gal/ton or higher) have more opportunities than those that are already doing well (10,000–15,000 gal/ton). Effluent reduction below 10,000 gal/ton is more capital intensive and brings in issues related to nonprocess elements (NPEs), equipment corrosion, effluent toxicity, and product quality. Figure 3 shows the relationship of effluent reduction efforts to the capital cost and process issues.

TYPICAL PROJECTS FOR EFFLUENT REDUCTION

A discussion of the most common projects for effluent volume reduction is presented in this section. Typically, all of them may not be applicable to a given facility. Implementation of these projects can reduce the effluent flow to 10,000–15,000 gal/ton of bleached pulp.

To achieve effluent flows below 10,000 gal/ton, significant process changes in cooking, washing, and bleaching areas are required. These include items such as oxygen delignification, nonchlorine bleaching, and the use of recently developed technologies for bleach filtrate recycle to the liquor cycle. Bleach plant effluent evaporation and incineration are also under development. These technologies are briefly described later.

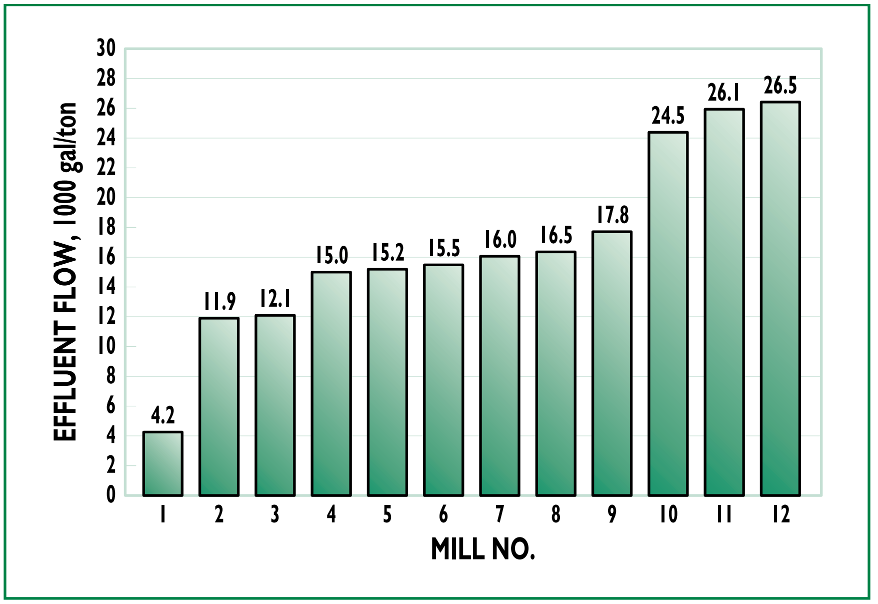
Water supply system upgrade

A good water supply system in a bleached pulp mill will include the following water supply headers:

- The raw water supply header will have treated water coming from the source such as the city supply or mill water treatment plant. This water is used for cooling tower makeup, chiller makeup, and seal water needs. The temperature of this water could vary with the season.

- The mill water supply header should ideally provide a year-round constant-temperature supply. The supply to this header typically comes from the raw water header, which is heated in the winter months using the secondary heat from the pulp mill and chemical recovery areas. This header supplies water for various process users in the pulp mill, paper machines, and utilities areas. It is desirable to keep this water separate from the cooling tower loop.
- The warm-water supply comes from a warm-water storage tank. The temperature of this water should be maintained at 110–120°F. The sources of warm water are heat exchangers in the pulp mill and evaporator surface condensers. This water is used to heat raw water in the winter periods.
- The hot water is generated by using blow heat in batch digesters or by using heat in the black liquor, in the case of a Kamyr digester. A good target temperature for hot water is 170–180°F. A hot-water tank provides the necessary storage for the hot water. Users of hot water include the bleach plant and the lime mud filter showers.
- The cooling water supply header receives the water from the cooling tower and supplies it to heat exchangers, coolers, and condensers in various process areas.
- The cooling tower return header collects the warm water from coolers, heat exchangers, and condensers and returns it to the cooling tower for cooling.

In an existing mill, it may not be cost effective to completely revamp the water supply system to provide all the headers previously mentioned. The modifications in a given facility will depend on the site-specific situation.



2. Effluent discharges from the bleached mills, gal/b.a.d.t.

Area	Older mill	Newer mill	Current design
Digesting	1.1	1.0	0.2
Washing & screening	4.2	1.8	0.2
Bleach plant			
Acid	25.0	21.0	5.0
Alkaline	30.0	10.0	5.0
Chemical preparation	0.5	0.8	0.2
Total fiberline	60.8	34.6	10.6
Pulp machine			
Rejects	1.3	1.3	0.2
General	5.2	4.9	0.2
Total pulp machine	6.5	6.2	0.4
Evaporators	0.7	0.6	0.2
Recovery	2.1	0.6	0.2
Hog/power boiler	4.9	0.9	0.5
Recausticizing	2.6	1.3	0.3
Total recovery/power	10.3	3.4	1.2
Grand total, m^3/a.d.m.t.	77.6	44.2	12.2
Gal/a.d.U.S.t.	18,624	10,608	2,928

II. Water usage in various process areas in bleached kraft mills (2). Units are m^3/a.d. metric ton.

Storage capacity for water and condensates

Good water management is the key to effluent minimization. This includes minimal overflows during process upsets and minimum makeup to the hot- and warm-water tanks. Adequate storage capacity for warm and hot water and process condensates can reduce the undue demand on fresh water during upset conditions, thereby reducing the effluent volume. Good process control and adequate communication between the operators in various departments are key to minimizing the overflows.

Proposed configuration	Water use, gal/ton pulp	Water savings, %	Steam use, lb/ton
Present operation	6830	-	3525
D-stage jump	4320	26.8	2100
D/Eo stage jump	3235	52.6	1520
Fully countercurrent	2000	70.7	680

III. Estimated effluent reduction and energy savings with bleach filtrate recycle

Proposed system	WATER SAVINGS gal/min	%	Est. cost, US$
Cascade system	455	45.5	160,000
Heat exchanger system	600	60.0	220,000
Cooling tower system	845	84.5	360,000

IV. Estimated savings and cost for vacuum pump seal water reduction

Bleach filtrate recycle and reuse

Recycle of bleach plant filtrate from the last D-stage to other acid stages and from the second alkaline stage to the first alkaline stage is practiced to reduce the effluent volume from the bleach plant. The concepts of jump stage and split flow countercurrent washing have been practiced in Scandinavian and North American mills for many years. Equipment parameters, metallurgy, and operating costs are the main considerations in choosing the degree of closure in an existing bleach plant. With bleach plant filtrate recycle, the water and heat consumption decreases while chemical consumption and corrosion increase.

In a three-stage bleach plant shower, water usage can be reduced by 60–70% with fully countercurrent filtrate flow. An intermediate level of recycling can be chosen to suit the plant conditions by choosing a jump stage configuration. The savings in water usage will obviously be lower. Table III presents the estimated effluent reduction and steam savings for a three-stage bleach plant with various closure options. The assumptions for these estimates include a brown high-density consistency of 12%, a washer feed consistency of 1.5%, a dilution factor of 1.0, and a displacement ratio of 0.81. The consistencies of the C_D, Eop, and D stages are assumed to be 10.5, 9.5, and 12%, respectively.

Paper machine vacuum pump seal water system upgrade

Vacuum pump seal water can significantly contribute to the effluent volume. The following methods have been used for reducing the fresh water required for this purpose.

Cascade system. The high-vacuum pump's seal water is collected and used as seal water in the low-vacuum pumps. The spent water from the low-vacuum pumps can be used in other areas in the paper machines, e.g., in the press section showers. This method can reduce the water consumption by 40–50%.

Heat exchanger system. In this method, all the seal water from the high- and low-vacuum pumps is collected and passed through a heat exchanger to extract the heat. Water from the mill cooling tower or other appropriate source can be used as cooling water. The cooled water is reused in the vacuum pumps. Savings in seal water usage of about 60–65% could be achieved by this method.

Cooling tower system. A dedicated cooling tower is used in this method to cool the vacuum pump seal water. A small portion of water is lost in evaporation and blowdown. The cooled water is pumped back for reuse in both high- and low-vacuum pumps. Savings of over 90% in seal water usage can be achieved by this method.

In a recent water conservation study for a mill with two small unbleached paper machines, the vacuum pump seal water consumption was 1000 gal/min. The three options previously mentioned were evaluated for reducing the water consumption. The results of this evaluation are included in Table IV.

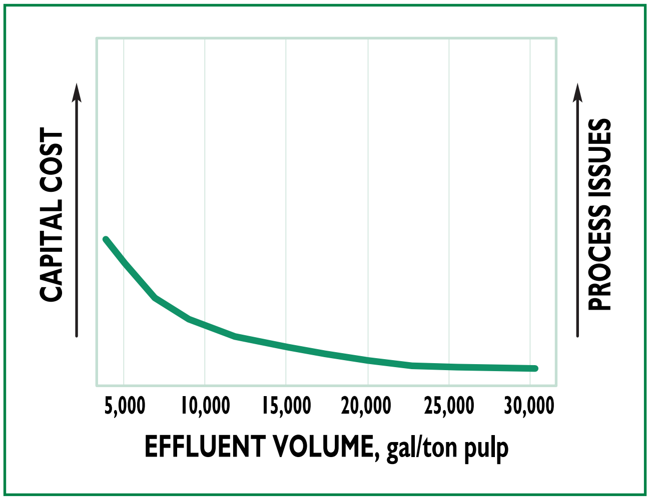
Other conventional projects not discussed in detail are seal water reuse, screen room closure, higher discharge consistency from washers, evaporator condensate reuse, white water recycle, and spill containment.

IMPACT OF EFFLUENT REDUCTION PROJECTS

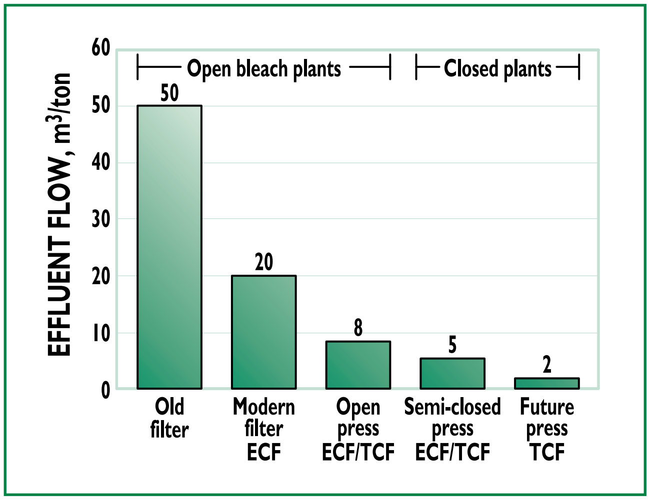
The reduction in the effluent volume resulting from the use of the projects will depend on the present status of the mill with respect to each project. For example, in the case of a mill that uses 50% of evaporator condensate on brownstock washers and sewers, installation of a condensate stripper will reduce the quantity of condensate being sewered. The stripped condensate from the sixth effect and the surface condenser can be used in the process, and the effluent quantity is often reduced. Some mills may have a partially closed bleach plant. If a project on bleach plant effluent recycle is undertaken, this mill will gain less compared to the mill that has a completely open bleach plant. A range of effluent volume reduction for different projects is presented in Table V.

NEW TECHNOLOGIES FOR EFFLUENT REDUCTION

In a typical bleached kraft pulp mill, effluent from the bleach plant constitutes 50–75% of the total effluent. In the state-of-the-art mills incorporating newer technology, the effluent from the bleach plant could contribute as much as 85% of the total effluent. For this reason, the efforts in research and industry have been directed to



3. Capital cost and process issues vs. effluent reduction



4. Bleach plant effluent reduction with new technologies

minimizing the quantity of effluent generated in the bleach plant. The chlorinated compounds have been a major hurdle in closing the conventional bleach plant. Many approaches, including the following, are being used to minimize effluent from bleach plants.

Project	Eff. reduction, gal/b.a.d.t.
Water supply system upgrade	0–2,000
Increased storage and better control for water and condensates	500–1,000
Stock and black liquor spill reduction	200–300
Seal and cooling water reuse	200–1,000
Higher mat consistency on brownstock washers	200–1,000
Closed screen room	300–1,000
Install condensate stripper and improve	

V. Estimated effluent reduction from conventional projects

Elemental chlorine-free (ECF) bleaching sequences

This approach is based on the use of the following technologies that were recently developed or are under development:

- Use of wash presses in the bleach plant
- Use of bleach filtrate recycle (BFR™) *(3),* developed by Champion International Corp./HPD/Sterling Chemicals. This process consists of the metal removal process (MRP) and the chloride removal process (CRP).
- Regeneration of bleach chemicals from bleach effluent for reuse
- Treatment of acid- and alkali-stage filtrate for incineration and disposal

Totally chlorine-free (TCF) bleaching sequences

This approach includes the following steps:

- Reduction of the kappa number going to the bleach plant by using chemical additives, such as anthraquinone and polysulfides, or by using modified cooking techniques, such as modified continuous cooking (MCC) and extended MCC, isothermal cooking (ITC™), black liquor impregnation (BLI), and Lo-Solids™ cooking.
- Use of oxygen delignification following low-kappa cooking
- Use of nonchlorine bleaching agents, such as ozone, peroxide, and peracids, to enable recycle of bleach effluent to liquor cycle.

These technologies have reduced the bleach plant effluent considerably. Use of wash presses compared to the filters can reduce the effluent by about 50% without any closure. Germgard *(4)* has presented the description of some modern bleach plants. For example, the Advance Agro mill in Thailand uses presses in a three-stage bleach plant. The bleach plant effluent volume is reported to be 8–9 m^3/metric ton compared to 20–25 m^3/metric ton in similar plants using vacuum washers. The decrease in bleach plant effluent with the use of newer technologies is presented in Fig. 4.

CONCLUSIONS

The pulp and paper industry has made significant progress in effluent volume reduction. Today's state-of-the-art bleached kraft mills have effluent volumes of less than 5000 gal/bleached a.d. ton (gal/b.a.d.t.). An effluent volume in the range of 2000–3000 gal/b.a.d.t. seems plausible to achieve in the next 3–5 years. Problems of nonprocess elements and issues of equipment corrosion will have to be addressed in order to achieve further reduction. **TJ**

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LITERATURE CITED

1. Bryant, S. P., *Malcolm, E. W., and Woitkovich, C. P., TAPPI 1996 Environmental Conference Proceedings,* TAPPI PRESS, Atlanta, p. 451.
2. Anon., *TAPPI Kraft Mill Closed Cycle Short Course Notes,* TAPPI PRESS, Atlanta, p. 188.
3. Caron, J. R. and Williams, L. D., *TAPPI 1996 Minimum Effluent Mills Symposium Proceedings,* TAPPI PRESS, Atlanta, p. 181.
4. Germgard, U. and Steffes, F., *TAPPI 1996 Minimum Effluent Mills Symposium Proceedings,* TAPPI PRESS, Atlanta, p. 115.