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Pulp and Paper Mill Water Use in North America

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PULP AND PAPER MILL WATER USE IN NORTH AMERICA

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ABSTRACT

Water use data from more than 650 mills in the United States and Canada have been analyzed for this study using the FisherPulp™ database. The database was validated by conducting a phone survey of 4% of the mills in the database. The use of fresh water by mills included in the study totals 6.5 billion gallons per day with the mean water use of 16,000 gallons per ton of product produced.

The mills in the database were subdivided into 11 categories representing process and product types. Large nonintegrated paper and board mills had the lowest median water use at 3,600 gallons per ton, while dissolving chemical pulp mills had the highest median water use at 41,400 gallons per ton.

INTRODUCTION

The U.S. paper industry significantly reduced water use between 1975 and 1988 with the mean water use per ton of product dropping from 26,700 gallons/ton in 1975 to 17,500 gallons/ton in 1988.¹⁻² This study suggests that further gains in paper industry water reduction have been made with the average water use dropping to 16,000 gallons per ton.

Some mills have been able to reduce their fresh water use by applying both conventional and new technologies. As a mill's fresh water use and subsequent effluent discharge decreases, the concentration of contaminants within water circuits builds up and can result in both increased production costs and reduced product quality. New economical technologies which purge water circuit contaminants are needed if water use in the paper industry is to be significantly reduced in the future.

The most recent comprehensive published data on U.S. paper industry use of fresh water are found in a February 1991, report from the National Council for Air and Stream Improvement (NCASI).¹⁻² This report presents results from a 1989 survey which represents approximately two thirds of the U.S. paper industry's 1988 production. NCASI had previously conducted water use surveys in 1975 and 1985.

Water use at a particular mill is determined by product type, process type, and mill practices. To adequately compare a mill's water use against industry averages requires that the data be categorized by a mill's principle products and processes. NCASI segregated its data into eight categories.

The categories are:

1. Sulfite mills.
2. Bleached kraft and soda mills.
3. Nonintegrated paper and board mills.
4. Mills producing paper and board from deinked waste paper.
5. Mills producing paper and board from mechanical (or related) pulps.
6. Unbleached kraft and kraft cross-recovery mills.
7. Semichemical mills.
8. Mills producing paper and board from nondeinked waste paper.

Category	Mean (gal/ton)	Median (gal/ton)	Sample Size (N)
Sulfite	49,600	51,100	8
Bleached kraft	24,000	23,500	33
Nonintegrated	19,900	16,300	30
Deinked waste paper	18,100	18,500	8
Mechanical pulps	15,100	15,300	10
Unbleached kraft	14,800	12,500	27
Semichemical	5,700	6,500	7
Nondeinked waste paper	2,850	2,330	12

Table 1. Fresh water use in the pulp and paper industry. Results of 1988 NCASI survey.¹

The water use data from the 1988 NCASI survey is summarized in **Table 1**.¹ The U.S. paper industry significantly reduced water use between 1975 and 1988 with the mean water use per ton of product produced dropping from 26,700 gallons/ton in 1975 to 17,500 gallons/ton in 1988.

DATABASE ANALYSIS

Water use data from the NCASI surveys are considered high quality because the data were gathered specifically for the water and effluent reporting purposes. However, the most recent data are eight years old. To supplement the NCASI surveys, a database search was conducted on the FisherPulp™ database to get daily mill water, production rates, and product grade information. The Fisher data were validated by comparing it with data from a direct phone survey of 27 randomly selected unbleached integrated mills. The Fisher database mean for the 27 mills was 11.3 ±1.6 Mgal/ADST at 95% confidence level, while the mean from the phone survey

Mill Type	Mills	Statistics (Thousands Gal/Ton)						Totals (millions)	
		Mean	± [†]	Median	Wt. Mean	High	Low	ADST/Yr [‡]	Gal/Day
Integrated Bleached	103	23.4	1.8	22.9	21.6	48.2	8.9	47.0	2,986
Integrated Unbleached	44	11.4	1.4	10.1	10.5	24.6	3.4	26.6	825
Paper Mill >100 tons/day	218	8.0	1.8	3.6	8.0	145.2	0.1	22.6	534
Bleached Market Kraft Pulp	32	22.4	2.2	23.0	22.0	34.0	11.3	11.3	730
Newsprint (mechanical pulp)	40	10.4	1.5	9.7	9.9	27.3	3.3	11.6	337
Corrugating Medium (NSSC)	21	6.4	2.1	4.5	6.6	21.1	0.7	5.2	100
Newsprint (mechanical & high yield chemical)	17	19.7	6.7	15.5	19.7	71.1	8.9	4.6	268
Deinked Secondary Fibers	36	9.7	2.1	9.5	10.5	21.9	0.1	4.0	124
Dissolving Pulp	8	51.0	15.2	41.4	44.5	84.4	25.3	2.4	316
Paper Mill < 100 tons/day	135	18.0	3.0	12.0	14.1	87.5	0.3	2.2	93
Market Sulfite, BCTMP & other	9	18.0	13.4	4.5	16.2	49.5	0.3	1.8	87

Table 2. Summary data of water consumption by mill type from FisherPulp™ database. [†] 95% confidence level of the calculated mean. [‡] Assumes 340 operating days per year.

was 10.9 ±1.6 Mgal/ADST at 95% confidence level, showing that the difference in the means is statistically insignificant.

The FisherPulp™ database includes current data on more than 700 U.S. and Canadian mills and is maintained by Fisher International of South Norwalk, Connecticut. Fisher updates the database on a continuous basis with the intention that no data be over one year old.

Water use data were available on 663 U.S and Canadian mills. These mills have a combined production rate of 410,000 air-dried short tons per day of pulp, paper, and board products and a combined fresh water consumption rate of 6.4 billion gallons per day.

Water use at a particular mill is determined by product type, process type, and mill practices. To adequately compare a mill's water use against industry averages requires that the data be categorized by a mill's principle products and processes.

The data retrieved from the FisherPulp™ database were segregated into 11 categories. This categorization was done with the intent of grouping mills with like products/processes into the same category.

Mills were segregated into the following 11 categories:

1. Integrated bleached chemical pulp and paper mills.
2. Integrated unbleached chemical pulp and paper mills.
3. Paper and board mills with total daily production rates greater than 100 ADT/day.
4. Bleached kraft market pulp mills.
5. Newsprint mills with mechanical pulping.
6. Corrugating-medium mills with NSSC pulping.
7. Newsprint mills with mechanical pulping and high-yield chemical pulping.

8. Paper mills with secondary fiber deinking.
9. Dissolving-grade chemical pulp mills.
10. Paper and board mills with total daily production rates less than 100 ADT/day.
11. Market pulp mills making BCTMP, CMP, sulfite, and other nonkraft pulps.

Summary statistics for mills by category are given in **Table 2**. The 95% confidence levels calculated for the mean values assume random normally distributed data. A weighted mean water use was calculated by dividing the total water use of all mills in a category by the sum of all mills' production rates in that category. Production units are in air-dried short tons. Of the 11 categories analyzed, mills producing paper and board with production rates greater than 100 tons/day had the lowest median water use at 3,600 gallons/ton. Dissolving pulp mills had the highest median water use at 41,400 gallons/ton. This 11-fold difference in water use illustrates the importance of segregating paper industry water consumption data by categories which have mills with like products and processes.

Fresh water use histograms are shown in **Figures 1-8** for the eight categories which have data from more than 20 mills. The histograms plot water use in thousands of gallons per ton of product against percent frequency. Percent frequency is the percentage of mills in a category which have water use within the defined range. For example, a percent frequency of 20 means that 20 mills out of a hundred use water within the range represented by the width of the bar graph.

In general, mills which have very high water use relative to others in their category either make specialty grade products and/or use processes built and designed prior to the 1970s.

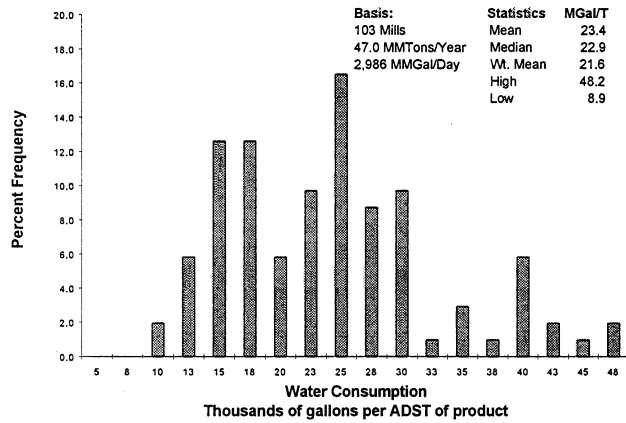


Figure 1. Water consumption histogram for integrated bleached chemical pulp and paper mills.

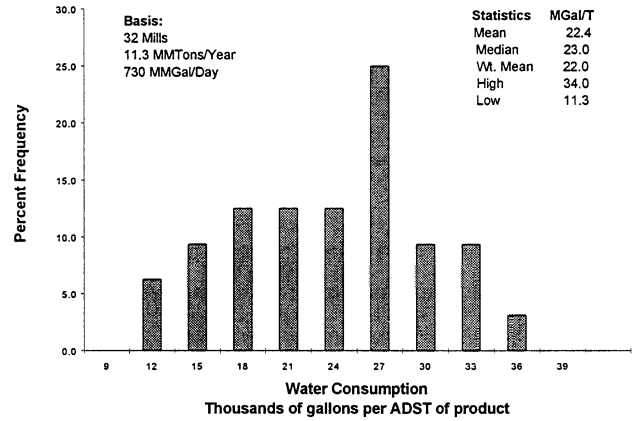


Figure 4. Water consumption histogram for bleached kraft market pulp mills.

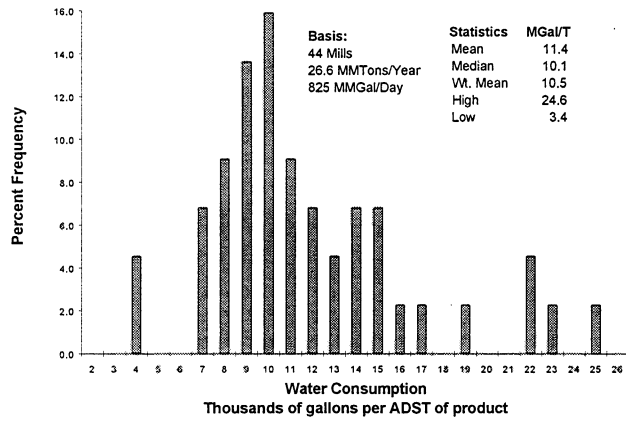


Figure 2. Water consumption histogram for integrated unbleached chemical pulp and paper mills.

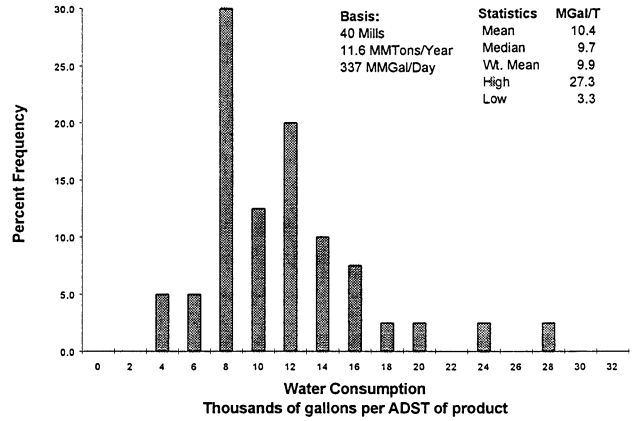


Figure 5. Water consumption histogram for integrated mechanical pulp and paper mills.

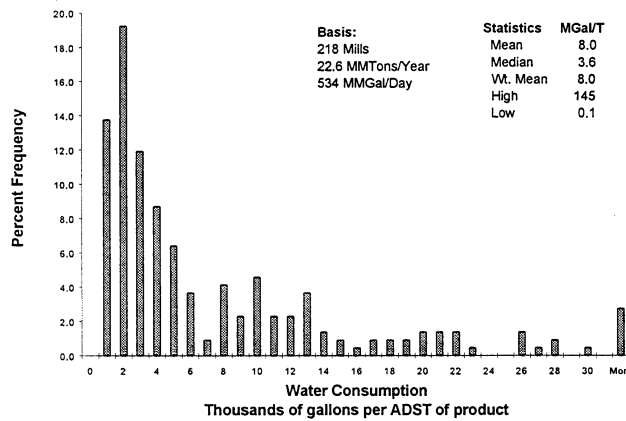


Figure 3. Water consumption histogram for paper and board mills with production greater than 100 ADST/day.

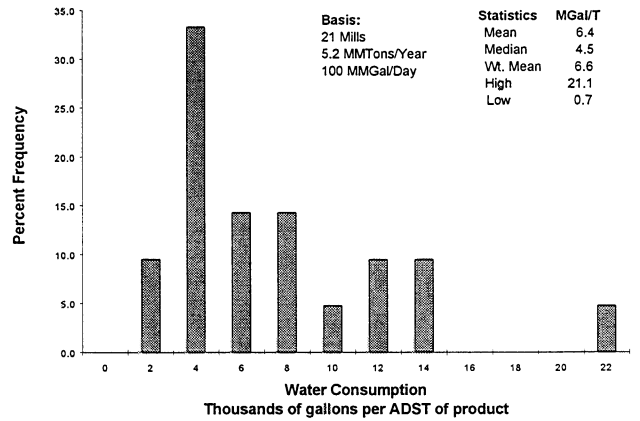


Figure 6. Water consumption histogram for integrated NSSC pulp and paper mills.

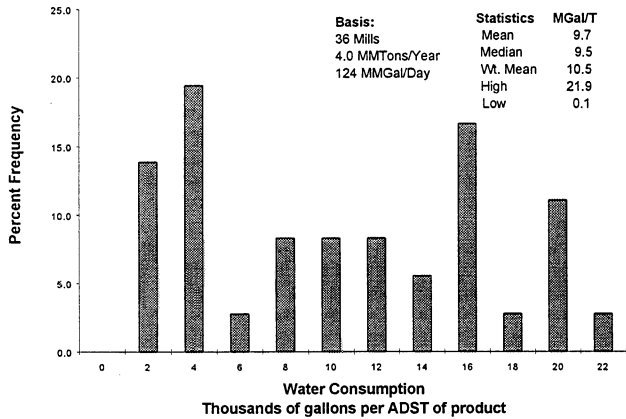


Figure 7. Water consumption histogram for paper mills with secondary fiber deinking.

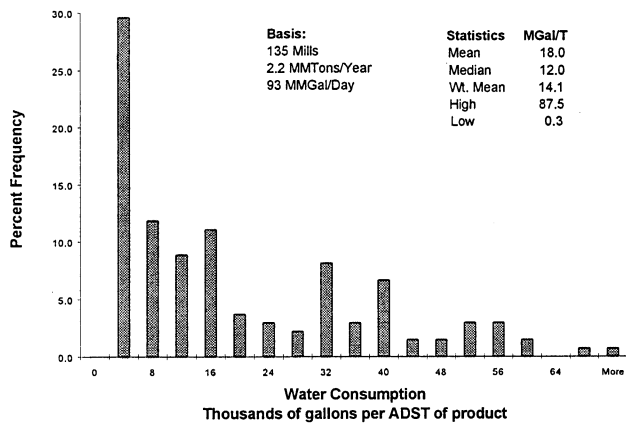


Figure 8. Water consumption histogram for paper and board mills with production of less than 100 ADST/day.

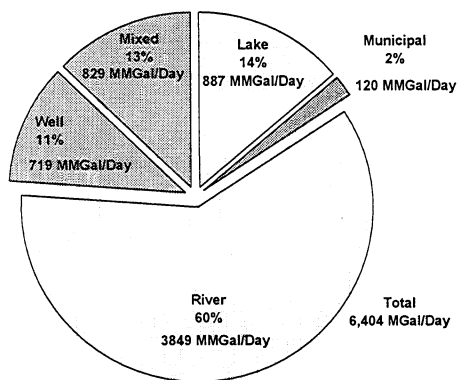


Figure 9. Water consumption by source of 663 mills in the United States and Canada.

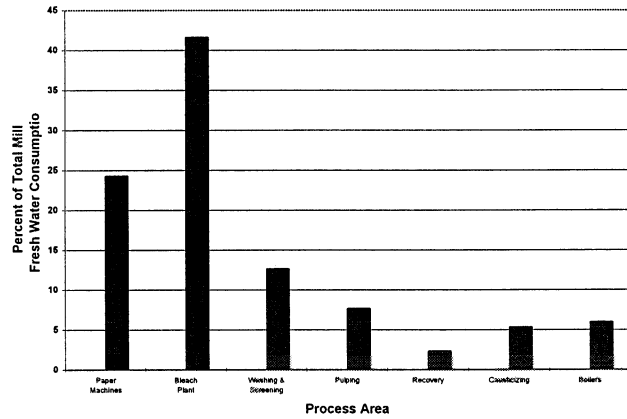


Figure 10. Water use by process area for typical integrated bleached kraft mill.

Mills using the least amount of water are those which were designed and built (or upgraded) in the last 15 years.

Integrated mills with very low water consumption rates typically have higher paper production rates relative to on-site pulp production rates. Therefore, caution must be used when trying to relate either high or low water consumption rates presented in **Table 2** to a particular mill's operation. For example, many unbleached integrated mills have expanded their paper or board production using recycled furnishes. As the relative production of virgin kraft pulp decreases, water use decreases, approaching that of nonintegrated paper mills at very low virgin kraft pulp production rates.

The mean water use for deinked recycle paper mills is 80% higher when comparing NCASI data to the Fisher data. Examination of the Fisher data histogram shows a bimodal distribution. The higher mean is likely related to tissue recycle and the lower mean to nontissue recycle mills. The difference between the Fisher and NCASI data may be due to inclusion of nontissue mills in the deinked recycle category Fisher data.

Paper mills with production rates of less than 100 tons/day use more than double the amount of water per ton of product compared to mills with production rates greater than 100 tons/day. This reflects the fact that specialty grades are made more often on small paper machines and that the average age of the small paper machines is higher.

The sources and amounts of fresh water used by the North American paper industry are shown in **Figure 9**. Rivers provide 60% of the fresh water consumed, followed by lakes at 14%, mixed at 13%, wells at 11%, and municipal at 2%. Lake water includes water from reservoirs. Mixed water is water coming from multiple sources which have not been broken down by individual source.

Water use by unit operation within the mill will depend on the processes and products made in a particular mill. For integrated bleached kraft mills, the bleach plant and paper machines are typically the largest users of fresh water. **Figure 10** shows the water use of a typical integrated bleached kraft mill broken down by process area.³⁻⁴

POTENTIAL FRESH WATER REDUCTION

Logically, the greatest potential for fresh water reduction exists in those areas of the mill which use the most fresh water. **Figure 10** shows that for integrated bleached kraft mills, the process areas with greatest potential for fresh water reduction are the bleach plant, the paper machines, and the pulp screens.

The amount of fresh water which can be reduced economically at a particular mill is dependent on the processes, the products, and the equipment age. Current process design of a fully bleached market kraft pulp mill would require approximately 15,000 gallons/ton of fresh water. Mills built more than 25 years ago were designed to use more than twice this amount of fresh water.

The SAPPI Ngodwana mill is the best documented example of achieving minimum water use in an integrated pulp and paper mill.⁵⁻⁶ The last phase of the mill started up in 1985. Minimum water use and discharge have been achieved through innovative engineering, tight operation, and a significant research and development program.

Because of special local circumstances, SAPPI has had to implement prototype and leading edge technology to minimize water use and effluent discharge. The SAPPI Ngodwana mill in South Africa draws its water from the Ngodwana River which has a total flow as low as 10 million gallons/day during the dry periods. The special circumstances of the Ngodwana mill that required the low-effluent design would most likely make a mill economically unviable in North America.

The mill's average water use is less than 4,500 gallons/ADMT. A water reservoir on the Ngodwana River stores up to one year's water supply for the mill. No effluent is discharged back into the river due to its limited flow and sensitivity of downstream users, but it is used to irrigate agricultural lands. The average effluent discharge is less than 3,500 gallons/ADMT. The difference between water use and discharge is due to evaporation.

The mill produces approximately 270 ADMT/D pressurized groundwood, 670 ADMT/D of unbleached kraft pulp, and 550 ADMT/D of bleached kraft pulp. The mill has a newsprint paper machine with a production of 350 ADMT/D, a

linerboard machine with a production of 500 ADMT/D, and bleached market pulp sales of 380 ADMT/D.

Even with updated process designs, there is a limit to the amount of fresh water consumption which can be economically reduced with current technology. Achieving low-effluent mill status while remaining economically competitive will require the development of new technologies and process knowledge.

Closing a mill's water circuits tightly can create many operational problems. One of the biggest problems associated with tightly closed water circuits is the concentration buildup of nonprocess elements (NPE's) in process streams. NPE's usually enter the process as trace constituents of raw materials. The relatively open water circuits of conventionally designed mills provide a significant purge for the NPE's, keeping their concentrations low.

One of the advantages of the kraft process is the high level of cooking chemical recovery. To illustrate the impact of recycle (or recovery) on trace contaminate buildup, the material balance of the kraft liquor cycle is represented by the simple single-recycle-loop process shown in **Figure 11**.

The accumulation factor graphed on the Y axis is the multiplier which represents the concentration of trace contaminants divided by the input concentration at the given recovery rate. For example, if the recovery process is 95% efficient, then one should expect there to be 20 times the amount of contaminants in the liquor cycle as in the input stream. At 99.9% recovery, the liquor cycle concentration is 1000 times that of the input stream. Clearly, as the recovery and recycle of kraft liquors increases, the concentration of trace contaminants can rise dramatically.

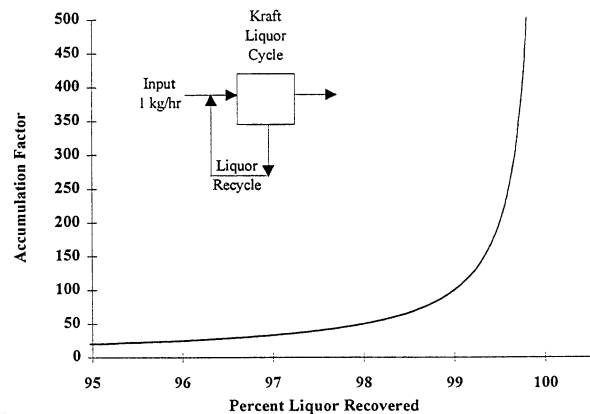


Figure 11. Mechanism of contaminant buildup in the kraft liquor cycle.

Since the economics favor a high recovery of process chemicals, it is desirable to have high liquor recovery. However, the accumulation of trace elements requires a controlled purge. In many parts of our processes, the technology for an economical purge of trace contaminants does not exist.

If mills reduce their fresh water consumption, they must design and operate their processes to keep the following potential problems under control:

- Scaling due to buildup of ions such as calcium, barium, aluminum, and silica.
- Recovery boiler plugging due to increased chloride and potassium concentrations.
- Pitch deposits due to increased concentrations of calcium and resin acids.
- Corrosion due to buildup of ions such as chloride.
- Equipment scouring and erosion due to suspended solids buildup.
- Increased biological growth in cooling water and white water circuits.
- Product contamination or odor due to dissolved solids carry-over.
- Increased chemical consumption.
- Increased waste-water temperatures.
- Imbalance of sodium and sulfur in kraft liquor cycle due to recovery of bleaching chemicals.
- Increased emissions of hazardous air pollutants.

Bleach Plants

Chemical pulp bleach plants have traditionally been the single largest users of fresh water in the mill with some bleach plants using more than 25,000 gallons/ton.⁷ The trend over the last 30 years has been toward short sequence bleaching with full counter current washing. Union Camp's Franklin, Virginia mill has been able to reduce fresh water consumption in its ozone-based bleach plant to less than 2,500 gallons/ton.⁸

Location	Low (gal/ADT)	High (gal/ADT)
Washer Showers	2,000	15,000
Doctors & Wire Showers	0	3,600
Brownstock H.D. Dilution	0	6,000
Chemical Makeup	400	1,800
Direct Steam	100	2,000
Total	2,500	28,400

Table 3. Typical Chemical Pulp Bleach Plant Fresh Water Use.⁷

Louisiana-Pacific's Samoa, California, mill reduced its fresh water makeup from 8,600 gallons/ton to 5,000 gallons/ton by converting its conventional (C+D)(EO)DED bleach plant to counter current washing.⁹ Most mills converted their bleach plant washers to partial or full counter current washing in the 1970s and 1980s for energy savings. Typical uses of fresh water in the bleach plant are shown in **Table 3**.

Bleach plant washer showers.

The purpose of the washer showers is to remove dissolved solids from the pulp by displacement prior to its entering the next bleach stage or the paper machines. Dissolved solids carry-over into a bleach stage increases chemical consumption and may negatively impact product quality. Fresh water to the washer showers can be reduced by substituting alternative reclaimed process water such as paper-machine white water or heat exchanger condensates and/or by operating the bleach plant washer showers in a counter current fashion with the downstream washer filtrates providing wash water to the upstream washers.

Reuse of reclaimed process water is dependent on a particular mill's water balance and is subject to product quality constraints. For example, the use of contaminated (pulp liquor organics) condensates or colored white water for bleach plant shower water is usually unacceptable.

Counter current washing may be limited by materials of construction, solids carry-over, and energy balance constraints. Newer mills have been designed with counter-current washing in mind, and the materials of construction in the bleach plant are acceptable for full counter current washing. Many older mills cannot achieve full counter-current washing because parts of the bleach plant are susceptible to severe corrosion when acid process streams are recycled from chlorine or chlorine dioxide stages.

Dissolving pulp grades are designed as chemical feed stocks instead of paper manufacturing. These grades have strict limits on trace contaminant levels. These product quality restrictions constrain both the quality of shower water used and the ability to run the bleach washers in a counter current fashion.

Washer doctors and wire showers.

Hydraulic doctors are used on many washer drums to aid in the discharge of pulp. Wire showers are used to clean the washer-drum face wire to maintain pulp drainage.

Hydraulic doctors can be replaced by air doctors or can use recycled process water if available. Fresh water use by wire showers can be reduced by using appropriate recycled process

water or by installing high-pressure, low-flow intermittent showers.

Brownstock high-density storage dilution.

Prior to feeding the bleach plant, pulp from the brownstock fiberline is normally stored at 10-15% consistency in high-density (H.D.) storage towers. The first stage of the conventional bleach plant may operate at either low (3%) or medium (12%) consistency. Most high-density storage towers required pulp to be diluted to below 5% consistency before it can be pumped out.

Fresh water dilution of the H.D. can be eliminated if filtrate from the first stage of the bleach plant is used. The materials of construction of the H.D. tower and/or the piping from the H.D. may either limit or prohibit the use of bleach-plant filtrates for dilution.

Chemical makeup.

ClO_2 , NaOH , NaOCl , H_2O_2 , and H_2SO_4 are chemicals used in pulp bleaching which are normally applied as low-concentration (1-10 wt%) aqueous solutions. Solubility limits, process control, and safety considerations restrict reducing fresh water input by increasing the concentrations of applied chemicals beyond their standard operating range. Clean recycled process water may be acceptable for replacement of fresh water as chemical make-down dilution water.

Direct steam heating.

With the exception of ozone, most bleaching reactions require temperatures between 60 and 90°C to proceed at optimum rates. Direct steam injection is the most economical way to heat pulp streams. Direct steam can be reduced by energy conservation and by indirect heating of shower water on the bleach washer prior to bleach stage.

Closed-cycle kraft pulp bleaching.

Great Lakes Forest Products' Thunder Bay, Canada, mill pioneered the closed-cycle bleached kraft mill in the late 1970s using the Rapson/Reeve process.¹⁰ The mill was forced to abandon closed-cycle operations in 1988 due to poor economics and operational problems.

Corrosion from high chloride concentrations and the buildup of trace nonprocess elements (NPE's) in the liquor cycle are the most significant challenges to closing the bleach plant by reusing bleach plant filtrates in the kraft pulping process.

Significant research and development is underway to address the problems encountered at Thunder Bay and to move toward the closed-cycle mills. As new commercial technologies become available, the industry will likely be able to reduce fresh water use significantly in the bleach plant.

Two new processes which are in the commercial implementation or demonstration stage in the United States are the Union Camp C-Free high-consistency ozone process and the Champion International Bleach Plant Filtrate Recycle (BFR) process.

Union Camp successfully started up its ozone system at its Franklin, Virginia, mill in September 1992. Fresh water reduction is accomplished by reusing the ozone and caustic extraction stage filtrates in a counter current fashion to postoxyggen delignification washers. This is possible because ozone-stage filtrate does not contain the chlorides found in conventional chlorine-based bleach-stage filtrates. Filtrates high in chloride concentrations cannot normally be reused in the brownstock fiberline because they lead to severe corrosion in the kraft liquor recovery cycle. The Franklin mill's last bleach stage uses ClO_2 , and its filtrate is sewered. A small purge of the acid-wash stage prior to the ozone stage is required to control calcium scaling. With a total bleach plant effluent flow of only 2,500 gallons/ton, the Franklin mill's ozone-based bleach plant has one of the lowest water use or discharge rates in the United States. Union Camp has licensed its ozone technology to at least three other mills: SCA in Sweden, SAPPI in South Africa, and Consolidated Papers in Wisconsin Rapids, Wisconsin.⁸

Champion International is starting up a demonstration unit of its BFR process at its Canton, North Carolina, mill in the fall of 1995. The BFR process reuses the filtrates from the first ClO_2 stage and the caustic extraction stage in a counter current fashion to postoxyggen delignification washers. Chloride concentrations in the liquor cycle are kept to acceptable levels by processing the precipitator dust from the recovery boiler through a crystallizer which removes chlorides and potassium and returns purified salt cake to the boiler. Metal cations are purged from the system by running the first bleach stage's filtrate through an ion-exchange resin bed. The BFR process should be capable of reducing effluent discharges and subsequent fresh water use to the same levels as the Union Camp C-Free process.¹¹

Chemical Pulp Screening

The purpose of screening pulp is to remove unwanted material selectively from the pulp stream prior to use in paper, board, or dissolving-grade products. The unwanted or rejected material normally consists of knots, shives, dirt, plastic, and other noncellulose debris.

Modern mills operate pressure screens with closed-filtrate systems. Some older mills operate open-filtrate screens with the filtrate sewered sent to waste treatment. Open-screening systems typically require 1,500-3,000 gallons/ton of fresh makeup water above that of closed-screening systems.

Mills that operate open-screen rooms usually do so for one of three reasons:

1. The mill has older atmospheric screens which cannot tolerate closed screening due to foaming.
2. The mill does not have adequate brownstock washing and runs open screening to reduce dissolved solids carry-over off the last brownstock washer (to bleach plant or paper machine).
3. The mill is recovery boiler limited and runs open screens to purge organics in order to reduce the load to the recovery boiler.

Paper Machines

Paper machines in the United States typically consume between 3,000 and 8,000 gal/ton of fresh water.¹² For integrated mills, this usually represents between 15-30% of the total mill water consumption.

Several paper mills have documented their fresh water reduction programs over the last 20 years.¹³⁻¹⁸ James River's Ypsilanti mill documented its water reduction program which resulted in a steady decrease of paper machine fresh water use from 24,000 gal/ton in 1973 to 6,500 gal/ton in 1983.¹⁹

The best opportunity for fresh water reduction on the paper machine usually involves reduction of fresh water used for machine showers and for vacuum-pump seal water.

Vacuum pump seal water.

Vacuum pumps are used to aid in the dewatering of pulp in the sheet-forming and press sections of the paper machine. Paper mills typically use either liquid ring vacuum pumps or centrifugal exhausters.²⁰ Centrifugal exhausters run without seal water, while the liquid ring vacuum pumps require significant flows of seal water, and open systems can account for up to one third of the fresh water use on a paper machine.²¹⁻²² A 1988 survey of 58 mills indicated that 77% of those surveyed had an active program in place for seal-water conservation.²³

Fresh water to liquid ring vacuum pumps can be reduced by either substituting clarified white water for fresh water or by running the seal water in a closed loop. In both cases, the system must be designed to control seal-water temperature, solids content, and biological growth. Temperature can be controlled with fresh water makeup, cooling towers, or heat exchangers. Solids buildup can result in unacceptable corrosion and must be controlled with a sufficient purge or with additional solids-removal processes. Closed seal-water systems must be treated with additives to control biological growth.

Paper-machine showers.

Showers are used primarily on the paper machine for cleaning and conditioning of machine fabrics and paper-machine rolls. Showers are also used for sheet doctoring and lubrication of wear surfaces that contact machine rolls with paper-machine fabrics.²⁴ Showers can represent the majority of fresh water used on the paper machine if clarified white water recycle is not utilized.^{15, 21} Most mills are currently operating a portion of their showers with recycled clarified white water.

Reuse of clarified white water for showers requires good clarification and proper shower design to prevent nozzle plugging and/or sheet defects. Use of fresh water is recommended for certain showers which are sensitive to higher concentrations of dissolved or suspended solids.²⁵

Cooling Water

Most mills have active conservation programs in place to recover cooling water and to segregate water by two or more temperature levels. These programs have been driven by energy conservation considerations in the past. Potential for reduction of fresh water consumption for cooling water is very mill-specific and depends on the mill's past efforts at energy conservation. Tools such as pinch analysis can help evaluate a mill's optimum energy-recovery strategy.²⁶

Fresh water consumption for cooling water which is not subsequently reused in the process usually results from unsteady state conditions during process upsets. Warm-water and hot-water tanks (and some process filtrate tanks) often make up with fresh water during process upsets because of low tank levels. In some situations, operators introduce fresh water for short-term upsets but fail to remove the makeup water when the upset condition has past. Many older mills have energy recovery systems which were retrofit long after initial start-up, making them complex and difficult for operators to understand.

Monitoring information systems can assist operations to optimize both energy recovery and minimized fresh water consumption for cooling water. Modern equipment design and process control systems can help minimize process upsets which result in fresh water makeup for inventory control.

Use of Alternative Water Supplies

In some cases, the impetus to reduce water is a shortage of water from a particular source such as groundwater, surface water, or municipally treated water. Substitution of water from other sources may be possible if economical alternative water supplies exist.

There are at least six paper mills that report using municipally treated waste water for a portion of their water supply.³

Concerns for worker safety, product contamination, consumer liability, and water quality must be addressed for each specific mill site investigating the use of treated waste water.

Some coastal mills may be able to substitute seawater for a portion of the fresh water used for cooling.⁴ The materials of construction must be designed to tolerate the corrosive nature of the seawater. The high chloride content of seawater restricts its use to noncontact cooling of process streams.

CONCLUSIONS

Water use data from more than 650 mills in the United States and Canada have been analyzed for this study. The use of fresh water by mills included in the study totals 6.5 billion gallons per day with the mean water use of 16,000 gallons per ton of product produced.

Water use at a particular mill is determined by product type, process type, and mill practices. To adequately compare a mill's water use against industry averages requires that the data be categorized by a mill's principal products and processes. The mills in the database were subdivided into 11 categories representing process and product types. Large nonintegrated paper and board mills had the lowest median water use at 3,600 gallons per ton, while dissolving chemical pulp mills had the highest median water use at 41,400 gallons per ton.

While some individual mills have been able to reduce their fresh water use by applying both conventional and new technologies, even with updated process designs, there is a limit to the amount of fresh water consumption which can be economically reduced with current technology. Achieving low-effluent mill status while remaining economically competitive will require the development of new technologies and process knowledge.

Closing a mill's water circuits tightly can create many operational problems. One of the biggest problem associated with tightly closed water circuits is the concentration buildup of nonprocess elements (NPE's) in process streams. NPE's usually enter the process as trace constituents of raw materials. The relatively open water circuits of conventionally designed mills provide a significant purge for the NPE's, keeping their concentrations low.

As a mill's fresh water use and subsequent effluent discharge decrease, the concentration of contaminants within water circuits builds up and can result in both increased production costs and reduced product quality. New economical technologies which purge water circuit contaminants are needed if water use in the paper industry is to be significantly reduced in the future.

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