Experience with water system closure at recycled paperboard mills

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ABSTRACT

A number of mills producing recycled paperboard operate zero discharge water cycles. In general, these mills elected to convert to zero discharge as the economical option to achieve environmental compliance given the specific manufacturing practices employed at these locations. Recently, EPA has proposed that all non-deinking recovered fiber mills (except those producing tissue toweling and molded products) classified as a New Source will be required to achieve zero discharge of process wastewaters. The objective of this study was to assemble information characterizing existing zero discharge operations to be used to assess the appropriateness of requiring all new non-deinking recovered fiber mills to achieve zero discharge. This information was obtained by conducting two separate surveys of zero discharge mills. The results of these two surveys are presented in this paper.

THE CURRENT CLIMATE OF INCREASingly stringent effluent regulations is causing some recovered fiber paperboard mills to consider closure of their process water system. The concept of a "zero discharge" mill can be attractive both from the standpoint of biological treatment plant savings as well as by eliminating the environmental impact of mill effluent. If promulgated as proposed, the Cluster Rule could require that non-deinking recovered fiber paperboard mills operate in a closed cycle mode if they become classified as a New Source (including installation of a new paperboard machine or replacement of an existing paperboard machine.) The degree of difficulty which a mill may encounter to achieve zero discharge is expected to vary depending on factors such as furnish makeup, product type, and product quality standards.

This paper presents the results of two separate surveys conducted to characterize manufacturing conditions and water use practices at zero discharge paperboard mills. The objective of the surveys was to assemble information needed to (a) evaluate the appropriateness of EPA's proposal that essentially all non-deinking recovered fiber mills (except tissue/toweling and molded products mills) be subject to New Source Performance Standards (NSPS) requiring zero discharge of process wastewaters and (b) estimate the cost to implement closed cycle technology at different types of recovered fiber mills. The two surveys included a telephone survey of 16 U.S. and Canadian mills conducted by BEAK Consultants, and mill visits by NCASI staff to nine zero discharge non-deinking recovered fiber mills. A majority of the mills visited by NCASI were also included in the BEAK survey.

OVERVIEW OF MILLS SURVEYED

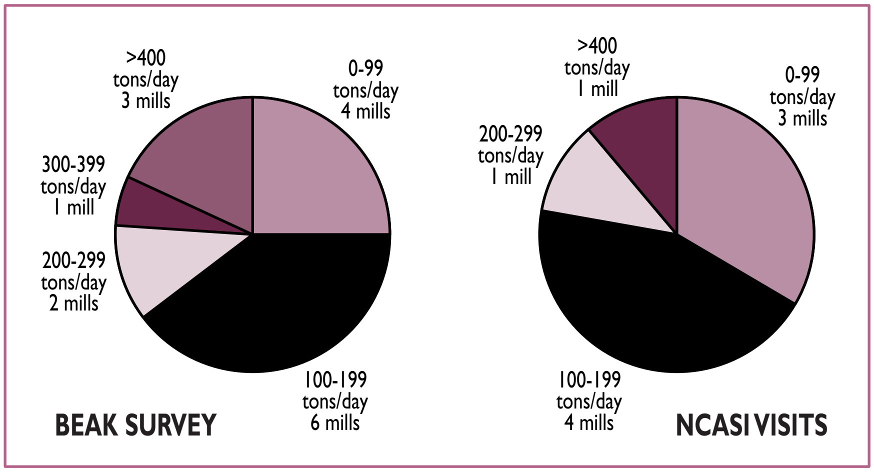
Mills to be included in the surveys were selected to include at least one mill in each product line subject to the NSPS requirement of zero discharge. The number of mills in each product category surveyed in the two studies is indicated in **Table I.** The distribution of mills surveyed is generally reflective of the total population of non-deinking recovered fiber mills* with the notable exception being the low occurrence of zero discharge coated paperboard mills relative to the number of coated mills in operation. Production rates at the mills surveyed varied from 50 to 600 tons/day among the 16 mills in the BEAK study and from 50 to 140 tons/day among the nine mills visited by NCASI. In both surveys, production rates were typically between 100 and 200 tons/day. Five of the nine mills visited in the NCASI study exhibited daily production rates falling within the lower quartile of the total population of "open" and closed mills within that production segment.* **Figure 1** displays the distribution of production rates at mills surveyed in the two studies.

Closed cycle paperboard mill operation is not a new concept. Five of the 16 mills in the BEAK survey have been zero discharge since the 1970s. The surveyed mills were generally not constructed to operate without effluent but closed their water loops incrementally. All of the nine mills visited by NCASI cited factors relating to compliance with either direct discharge permits or pretreatment conditions imposed by a municipal wastewater treatment plant as the primary reason for zero discharge implementation.

Of the nine mills visited by NCASI, only five unquestionably meet EPA's definition of zero discharge of "a system where the sum of fresh water and water entering the system in raw materials is equal to the sum of water exiting the system via evaporation/vaporization, water in the final product, and water included in any rejects streams from screening, including sludges." The status of two of the remaining mills

* Barton, D. A. and Ahearn, P. S., *TAPPI 1995 International Environmental Conference Proceedings*, TAPPI PRESS, Atlanta, p. 233.

is subject to interpretation of the zero discharge definition (one mill discharges basement waters, potentially contaminated with process waters, under emergency conditions and the second mill discharges various mill condensates and boiler blowdown), whereas two of the mills clearly do not meet the EPA zero discharge definition because of the presence of continuous or semicontinuous process water discharges.



1. Distribution of production rates at mills surveyed

Mill category	NUMBER OF MILLS BEAK survey	NCASI visits
Coated paperboard	0	1
Uncoated paperboard	3	1
Corr. med/kraft paper	4	3
Linerboard	2	0
Chip and tube	4	3
Roofing felt	3	1

I. Distribution of type of mills included in surveys

MANUFACTURING PRACTICES

Furnish makeup

The mills visited in the NCASI study appear to use furnish of equal or higher quality than the "typical" furnish makeup reported in the 1994 NCASI/RPTA/EPA questionnaire.* A higher quality is defined here to mean: (a) relatively clean of contaminants [often pre-consumer waste such as boxboard cuttings and double lined kraft (DLK)] with extensive pre-sorting and (b) containing fiber with relatively high freeness [especially DLK, old corrugated containers (OCC) and hard mixed whites]. At the mills visited which produce folding paperboard, corrugated medium, kraft paper, and chipboard, the furnish appears to be of a higher quality than that typically used by other mills manufacturing these products. At the mills producing bookboard and roofing felt, the furnish appears to be comparable to other mills manufacturing these products. **Table II** provides a summary of the comparison of furnish at the visited mills versus furnish makeup reported in the 1994 questionnaire.

Process equipment

Pulping is accomplished without the use of direct steam in approximately one quarter of the mills surveyed. Both batch and continuous pulpers are used in the zero discharge mills. Pulping temperatures range from 21°C to 57°C in the closed cycle mills, and pulping is usually followed by two or more stages of screening.

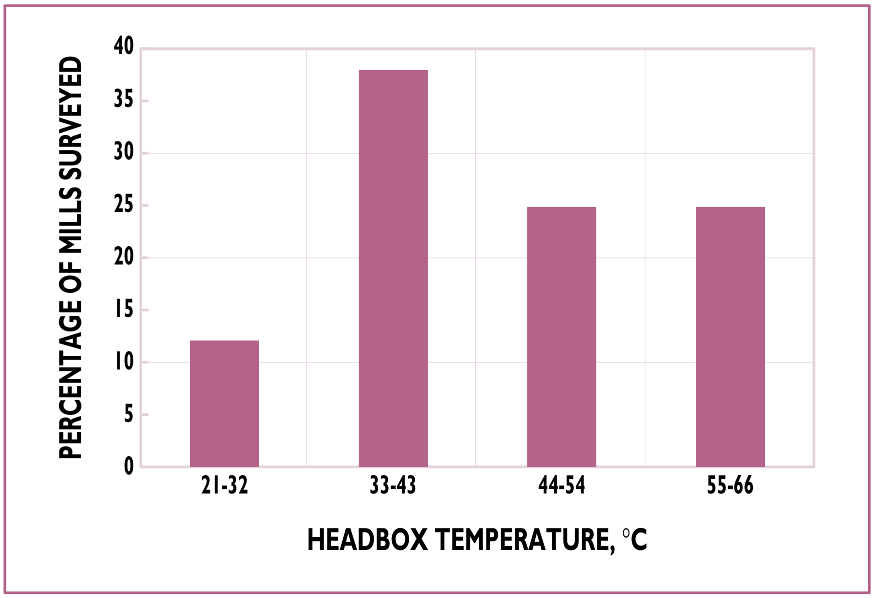
Stock preparation facilities are generally not sophisticated in the surveyed mills. Pressure screen technology is used in a majority of mills; however, several use flat vibratory screens instead. Generally one or two stage cleaning is used, followed by disc refiners. Rejects from these operations are usually compacted in order to minimize sludge moisture prior to disposal.

Most of the paperboard machines being used are between 25 and 40 years old, having been rebuilt as recently as 1991, and as long ago as 1972. The kraft paper, corrugated medium, and linerboard mills have fourdrinier formers while the paperboard, boxboard, insulation board, and roofing felt mills generally operate cylinder machines.

Whitewater and headbox temperatures for closed cycle mills are traditionally expected to be higher than for open mills because the process heat is recovered in the recycled water rather than removed with the effluent. However, headbox temperatures for the mills surveyed vary from a low of 24°C to as high as 60°C. The range of temperatures is summarized in **Fig. 2**.

Chemical programs

Chemical programs for closed cycle mills must be carefully controlled to achieve good first-pass retention of chemicals, fiber, and contaminants. Otherwise, a buildup of fines, size, pitch, and filler in the whitewater



2. Headbox temperatures at zero discharge mills

Primary product	Furnish makeup at mills visited	Typical furnish makeup for production segment[a]
Folding paperboard (2 mills)	Boxboard cuttings, DLK, OCC (Liner: SBS, CPO)	20% ONP; 20% OCC 30% Boxboard cuttings 20% SBS; 5% DLK
Kraft paper	DLK	60% DLK; 40% OCC
Corr. medium (2 mills)	100% OCC OCC & DLK	100% OCC
Chipboard (2 mills)	Boxboard cuttings, mixed paper (Liner: DLK, OCC & white kraft)	50% OCC; 20% mixed 20% ONP
Bookboard	Mixed paper, file stock OCC & ONP	40% mixed; 30% OCC 15% ONP
Roofing felt	OCC, ONP & TMP	50% OCC; 20% mixed 5% ONP; 25% TMP

[a] Based on 1994 NCASI/RPTA/EPA questionnaire
DLK = double lined kraft. OCC = old corrugated containers. SBS = solid bleached sulfate
ONP = old newspapers. TMP = thermomechanical pulp. CPO = computer printout

II. Comparison of furnish makeup of visited mills versus 1994 questionnaire results

can result in paper machine deposits and breaks.

Mills which require size, such as linerboard, folding paperboard, or insulation board mills, may use rosin size, although high whitewater pH reduces its effectiveness. ASA or AKD synthetic sizes have a greater pH range, but they hydrolyze easily and must be well retained in the sheet. A few of the closed mills visited currently use synthetic size. However, one coated paperboard mill reported that conversion to zero discharge operation has precluded the use of internal sizing.

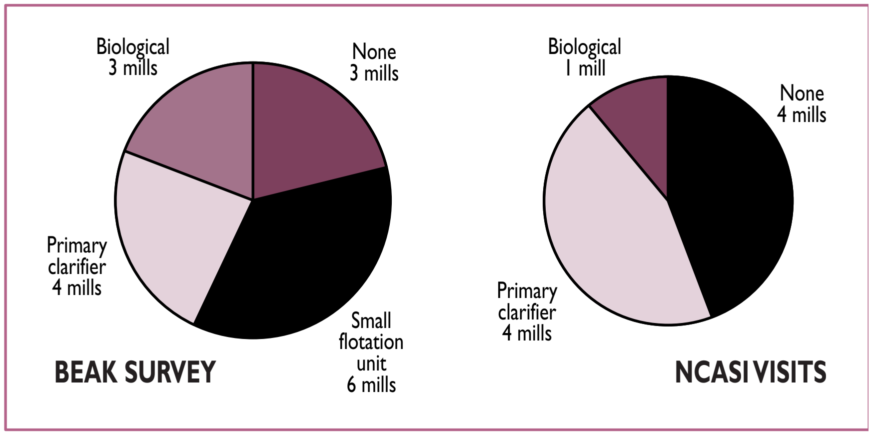
Starch is generally avoided in closed cycle mills because of its tendency to hydrolyze and remain in the recycled water. This starch acts as a food source for unwanted slime and bacteria, which can become a significant problem in terms of both product quality and corrosion. Dry size application with a size press at the dry end of the machine is being used increasingly by European closed cycle mills. However, the use of dry size agents may introduce concerns with respect to broke recyclability, especially when dry-end starch is used. Neither of the two folding paperboard mills visited in the NCASI study use dry-end starch, whereas 80% of the "open" mills producing folding paperboard responding to the 1994 NCASI/RPTA/EPA questionnaire indicated use of this additive.[*]

Product quality objectives

Comparison of product quality among either open or closed recycled paperboard mills is difficult. Many recycled paperboard mills operate in specialized market niches and manufacture products of adequate quality within that niche but which may be deemed unacceptable for other uses. While there was no explicit attempt to solicit quantitative product quality information in this study, a general assessment of the product quality attained at the mills visited is that products equivalent to that of standard products commonly produced by open mills can be achieved; however, premium quality products may not be achievable in some cases. Production at five of the nine mills visited is produced primarily for internal use by the parent company.

Although product quality concerns are an important issue relative to zero discharge operation, there appears to be a need for quantitative information defining the impact on product quality which may result due to closure of the water system.

Much of the information obtained during the mill visits was of an anecdotal nature. For example, personnel at two of the mills visited stated that products produced at those mills could not compete with similar products produced from virgin kraft. Production at both of these mills is used internally by the parent corporation. This opinion was not necessarily expressed at other locations.



3. External treatment provided at zero discharge mills

WATER USE PRACTICES

On average, slightly over 1 m^3/metric ton (290 gal/ton) of process makeup water is required by the surveyed zero discharge mills. The total flow into the mill including non-contact cooling water ranges from 2.5 to 8 m^3/metric ton production, the average being 4.1 m^3/metric ton.

Points of freshwater application

Operation in a zero discharge mode requires judicious use of fresh water. At most of the nine zero discharge mills visited by NCASI staff, the primary application points of fresh water include paperboard machine showers (wire, cylinder, and felt showers, etc.) and pulper water, especially at mills producing white top or colored grades. At the two mills which use freshwater for vacuum pump seal water, makeup to the vacuum pump seal water loop is the primary point of freshwater usage.

Table III presents up to three primary freshwater application points at each of the mills visited. It should be noted that in some cases, fresh water makeup originates as non-contact cooling water. In addition to the application points identified in the table, freshwater is used for process pump seal water at many of the mills visited, although mechanical seals are used in some applications.

PRIMARY PRODUCT	FRESHWATER APPLICATION POINTS No.1	No.2	No.3
Fold. paperboard (2 mills)	Vac. pump seal water loop	Top liner pulper	
	Cylinder showers	Coating prep.	
Kraft paper	Process pump seal water	Washup hoses	Shower water makeup
Corr. medium (2 mills)	Wire & felt showers		
	Wire & felt showers	Sidehill screen washdown	Process pump seal water
Chipboard (2 mills)	Vac. pump seal water loop	Cylinder & felt showers	
	Top liner pulper		
Bookboard	Pulper		
Roofing felt	Some PM showers	Doctor blades	TMP process

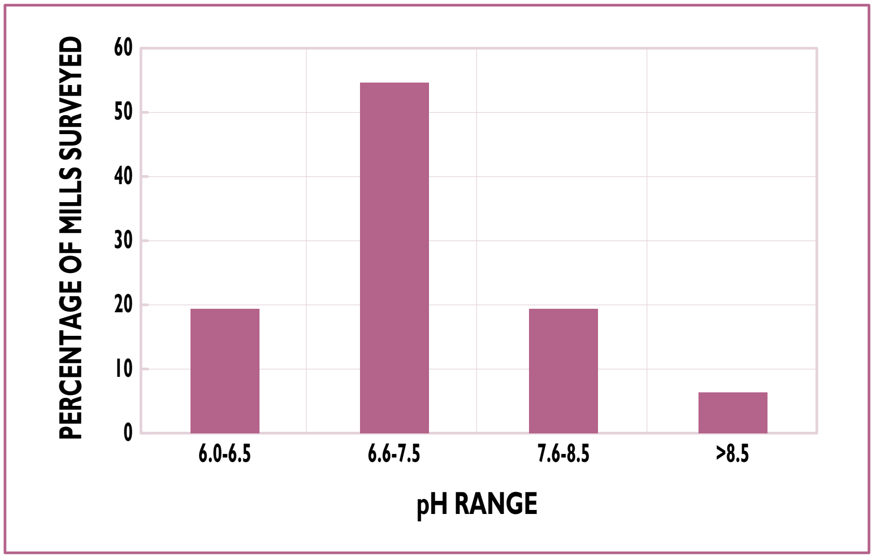
III. Primary application points of freshwater at zero discharge mills visited

A segregated cooling water system and sewer exist in three-quarters of the mills surveyed. About half of the mills also have a segregated rainwater sewer in order to prevent excessive sudden water intake which would then need to be stored and gradually assimilated into the process.

Water source for process applications

The three primary points of water usage in a non-deinking recovered fiber mill are: (a) pulper water and stock prep consistency control, (b) paperboard machine showers, and (c) vacuum pump seal water.

Pulper and stock prep consistency control. At the mills visited, clarified whitewater or saveall cloudy water was used at all Hydrapulpers providing pulp for (a) filler layers for multicylinder paperboard machines or (b) mills operating a single stock prep line (e.g., fourdrinier or single cylinder machines). Liner and underliner pulpers generally used recycled vat water from the liner and underliner cylinders. Initial batches of white or colored



4. Process water pH distribution

Surge basin capacity (m^3)	Number of visited mills
No external basin (water chests only)	1
Less than 400	4[a]
400 to 2000	3
Greater than 2000	1

[a] One mill has a lagoon in addition to a surge basin

IV. Surge basin capacity at zero discharge mills visited

grades required partial or complete substitution of fresh water for recycled process water. Stock prep consistency control was generally accomplished using clarified water or saveall water.

Paperboard machine showers. Plugging of paperboard machine shower nozzles is often cited as an obstacle for the use of recycled whitewater as the shower water source. Among the zero discharge mills visited in this study, only two mills (operating fourdrinier type paper machines) use fresh water for wire and felt shower water. One mill operating a cylinder machine uses fresh water for some of the cylinder showers, but clarified and strained whitewater is used for the felt showers. An additional mill indicated that freshwater is sometimes used on some paper machine showers and doctor blades, although during the NCASI visit it was observed that clarified effluent was being used at these applications.

The remaining five mills used either clarified whitewater which has been passed through a strainer (three mills) or "clear" whitewater used directly from the whitewater saveall (two mills).

Vacuum pump seal water. At mills striving to maintain a closed water balance, the use of fresh water for vacuum pump seal water can represent a significant portion of the total fresh water brought into the mill. On the other hand, use of warm process water results in a loss of vacuum pump efficiency, thereby requiring additional power consumption.

Seven of the nine mills visited use process water (approx. 50–60°C) for vacuum pump seal water, thus sacrificing vacuum pump efficiency in exchange for control over the mill's water balance. The process water source is generally a clarified water tank and special pretreatment (e.g., straining) of the water is typically not practiced. Vacuum pump seal water at one mill is passed through a 20 mesh stainless steel sidehill screen prior to use. All of the mills discharge contaminated vacuum pump seal water to the process water system rather than being discharged from the mill.

The two remaining mills operate fresh water loops, without a cooling tower, for vacuum pump seal water. Seal water contaminants are believed to settle out in the storage tanks comprising part of the loop. At both mills, the vacuum pump seal water loop is a primary fresh water makeup point which helps to lower the seal water temperature. Water makeup to the production process is drawn from the vacuum pump seal water loop.

PROCESS WATER TREATMENT

External treatment

External treatment is defined here as unit processes which treat the total mill effluent. This flow may include process water, floor drains, basement sumps, collected roof/ yard runoff, etc. In comparison, whitewater cycle treatment (e.g., savealls) is restricted to whitewaters collected from the paperboard machine.

Figure 3 shows that the majority of mills contacted in the BEAK survey possess primary treatment of some sort; however, only 19% use biological treatment. Similar results were obtained by the NCASI survey. In the latter study, four mills were observed to have no external unit process with the specific function of providing treatment, four mills provide gravity clarification only, and

KEYWORDS
Board mills, closed systems, discharge permits, effluent treatment, EPA, evaluation, mills (factories), reclaimed fibers, recycling, regulations, standards, surveys, waste waters, water management, white water system.

one mill provides flotation clarification plus biological treatment.

Common attributes among the four mills providing no external treatment are (a) manufacture products with minimal to no appearance specifications (e.g., corrugated medium, bookboard, kraft paper) and (b) operate fourdrinier (single ply) or single cylinder paperboard machines, thus having no opportunity to incorporate clarifier sludge into filler layers of the sheet. Among the mills providing some form of external treatment, four of these mills manufacture folding paperboard or chipboard on multicylinder paperboard machines. At each of these four mills, separate whitewater systems are maintained to segregate the relatively clean liner whitewaters from the remaining mill waters. Liner whitewaters are typically reused directly at the liner Hydrapulper with the remaining water (filler whitewaters and miscellaneous mill waters) treated in the primary clarifier for reuse. An additional attribute common to these four mills is the reuse of clarifier sludge within the filler layers. The fifth mill providing gravity clarification operates a single cylinder paperboard machine (roofing felt mill) and incorporates clarifier sludge into the final product.

The one mill providing biological treatment utilizes a sequencing batch reactor (SBR) process. A sidestream drawn from the surge basin is treated in the SBR process and, under normal conditions, is returned to the surge basin. The quantity of water receiving secondary treatment is approximately 7 m^3/ton of product. During periods of high groundwater infiltration, a portion of the biologically treated effluent may be discharged to the receiving stream under conditions of the mill's NPDES permit.

Surge capacity

A significant operating concern expressed by personnel at the zero discharge mills visited is the need to balance process water inventories with demand. This situation is particularly acute at mills which (a) periodically produce grades requiring fresh water (e.g., white liner or colored grades) and/or (b) are subject to periodic groundwater inflows to the water system. Adequately sized and properly operated surge basins are often needed to maintain zero discharge operation. It should also be noted that it is not uncommon for "open" mills to utilize external surge basins to enhance the degree of water recycle practiced within these mills.

The results of the BEAK survey suggest that for mills which have exterior storage, the average volume of surge capacity is approximately 1.3 m^3/metric ton of production. **Table IV** summarizes the relative size of the surge basins present at the nine mills visited in the NCASI study. The one mill with no external surge capacity produces a single product type (of varying basis weights) with no white or colored grades. Surge basin capacity at the four mills which run white and/or colored grades fall in the less than 400 m^3 category (two mills, one of which also has a lagoon for emergency conditions) and in the 9400–2000 m^3 category (two mills). Average external storage capacity at these nine mills is approximately 4 m^3/ton.

OPERATIONAL CONCERNS

Paperboard machine operation

Elevated headbox temperatures can result in fogging problems around the machine, especially during winter in cold climates. In the BEAK survey, just over half of the mills which have headbox temperatures above 38°C reported a fogging problem, especially during winter months. Large roof fans around the paper machine wet end are used by most of the surveyed mills, and one mill is using specialized closed hood wet-end ventilation.

The NCASI mill visits revealed that all of the mills which had recently closed the mill's water cycle required changes to the wet-end chemistry as a result of closure. This is consistent with the results of the NCASI/RPTA/EPQ questionnaire in which wet-end chemistry changes were commonly cited as a key challenge facing mills considering water system closure. The buildup of fines, and the associated reduction in drainage rates, was cited as a major factor necessitating a change in wet-end polymer usage at the mills visited. Specifics of other wet-end chemistry changes were not asked during the site visits. One mill reported a drop in whitewater pH following closure, presumably due to the production of short chain acids by anaerobic bacteria.

Another concern commonly cited regarding closed cycle operation is reduced felt life due to a high level of whitewater contamination which causes felt filling. The mills questioned reported replacing press felts due mostly to mechanical wear, as often as every month, or as infrequently as every 6 months. One mill noted 70 mg/L of suspended solids as the shower water quality threshold below which it does not have problems with the press felts. The use of a continuous chemical felt conditioner is one technique used to improve felt life. However, all mills but one use only a batch caustic felt wash. It was noted that judicious use of felt cleaners is necessary since the used felt cleaner will remain in the process water cycle at a zero discharge operation.

Plugging of shower nozzles due to a high concentration of solids in the shower water is often associated with water closure. High pressure purgable and internal brush nozzles are self-cleaning shower technologies used by 60% of the mills surveyed. Fresh water is often used on the high pressure machine showers, whereas clarified whitewater containing suspended solids as high as 600 mg/L is used on low pressure shower applications. In-line shower water filter baskets constitute another technical method of plugging prevention. This alternative is used in approximately one third of the mills. Steam showers are also used on machines in one quarter of the mills.

Some mills reported the development of odor in the sheet following conversion to zero discharge. The use of an appropriate biocide was generally successful in controlling the odor. Some odor from external treatment processes was detected during the mill visits. One mill indicated the presence of slime holes in the sheet and suggested these can be tolerated because the product is used within the company in applications with minimal appearance requirements.

Metallurgy

The recirculation of mill process water can result in increased corrosion of wetted equipment and piping. Low pH can combine with the increased dissolved solids in the water to create significant problems. Neutral pH operation is achieved naturally by many of the recycled fiber board mills. Only 20% of the surveyed mills add caustic or lime specifically to raise the pH of the process. Caustic addition points include the clarifier, the pulper, and the machine chest. The distribution of operating pHs are summarized in **Fig. 4**.

The use of stainless steel for wetted process equipment in zero discharge mills is widespread, and was described by most mill personnel as necessary. In the mills which use very little stainless steel, the process pH is maintained at a high level (>8).

CONCLUSIONS

Based on information assembled by two separate surveys, we can draw the following conclusions characterizing recycled paperboard mills operating zero discharge water systems:

1. The furnish used by these mills appears to be of equal or higher quality than the average furnish at other mills producing similar products. Stock prep stages and paperboard machine additive usage is generally reflective of that reported for mills operating open water cycle mills. At some locations, superior quality furnish is necessary to offset the need for additional fiber cleaning stages.
2. Products manufactured at these facilities can be described as exhibiting product quality ranging from "discounted" quality to quality equivalent to that of "standard" products commonly produced by open mills using recovered fiber. However, additional information is needed to establish the relationship between zero discharge operation and the quality of products produced.
3. Considerable whitewater surge capacity is needed for zero discharge operation, especially where white lined or colored grades are manufactured. Surge capacity at the mills surveyed in these studies averaged roughly 1 to 4 m^3/metric ton product.
4. All but one of mills visited by NCASI maintain zero discharge by providing either no external treatment or external treatment in the form of gravity clarification only. Only one of the nine mills visited provides biological treatment. External treatment requirements may be different for mills manufacturing products not represented among the mills visited.
5. Operational difficulties which may be encountered due to closure of the mill water cycle include: (a) fogging in machine area, (b) wet-end chemistry changes, (c) reduced felt efficiency, (d) reduced vacuum pump efficiency, (e) development of slime holes or other imperfections in the sheet, and (f) odor, either in the sheet or emanating from external treatment processes. Furthermore, accelerated corrosion rates associated with zero discharge dictate the need for stainless steel process equipment and piping. **TJ**

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