

## POLLUTION ABATEMENT IN FIBER BUILDING BOARD MILLS—1974

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**Abstract**—Different methods for treatment of the effluent from fiber building board production are discussed in relation to the current status in the industry.

The following alternative measures for reduction of the BOD-load are summarized:

1. Increased pulp yield, by variation in defibration conditions and by selection of the raw material.
2. Reduced fresh water consumption, up to a total closure of the white water systems.
3. Evaporation of concentrated waste water.
4. Fodder yeast production with waste water as substrate.
5. Chemical treatment of waste water.
6. Biological treatment of waste water.

Possible combinations of the above mentioned methods are discussed. A few examples are given of present approaches in different fiber building board mills.

A few years ago a BOD discharge equivalent to about 80 kg of oxygen per ton of board still occurred in a number of fiber building board mills, whereas today some mills report almost a zero discharge.

This paper reviews the progress made in pollution abatement for the wet process for fiber building board over approximately the last four years. Earlier knowledge was reviewed by Gran<sup>1</sup> at the 1972 IUPAC Conference on Industrial Waste Waters and Wastes, and is only briefly discussed here.

In the competition between different boards and processes for their manufacture, the cost of pollution reduction nowadays considerably influence the total costs and investments and the product's properties are affected by the pollution abatement methods adopted. This is especially true of the comparison between the wet and dry processes for fiber building boards, with air pollution in the dry process and water pollution in the wet process.

### 1. THE WET PROCESS AND ITS EFFLUENT

Figure 1 presents the wet manufacturing process for hardboard or medium density board, according to the Asplund process. Chips or sawdust are steamed in a pressurized preheater, at a gauge pressure of about 1.0 MPa. The thermally and hydrolytically softened wood chips are then defibrated in a pressurized disc refiner, and the pulp is blown to a cyclone. In some cases, the pulp is further refined in one or more disc refiners. The stock is diluted to a consistency of about 2% and a sheet is formed. The wet sheet is cut, and then either hot-pressed to hardboard or medium density board, as illustrated in Fig. 1, or dried to insulating board of a lower density. The hardboard is subsequently subjected to a heat treatment and then reconditioned, i.e. remoistened.

The main positions where water enters or leaves the process are marked in Fig. 1 by arrows.

The moisture content in the wood raw material is normally about 50%, which is equivalent to about one cubic meter of water per ton of board. About half a cubic meter per ton is added as steam in the preheater, and another 0.3 m<sup>3</sup> as sealing water in the pressurized disc refiners. Fresh water also enters as sealing water in subsequent refiners and pumps as dilution water for

additives, and large quantities as shower water on the forming machine. The total amount of fresh water is perhaps 15 or 20 m<sup>3</sup>/ton, of which the shower water often comprises 7-10 m<sup>3</sup>. The measures discussed below, such as intermittent showers, will certainly reduce these figures. A top layer pulp stock diluted with fresh water will add another 5 m<sup>3</sup> of fresh water per ton.

Most of the water leaving the process is surplus water from the water system. A heavily polluted water also leaves from the hot press. Some water leaves in the form of steam from the cyclone, from the hot press and from the dryer in the case of insulating board.

Chip washing produces a fairly polluted water which is pressed off by the inlet screw to the preheater. Most of this water can, however, be recycled in the chip washing system. It might also be possible to use white water for chip washing.

Most mills have separate flow systems for less polluted waters, e.g. for shower water from wires and felts. Non-polluted sealing and cooling water is discharged separately.

The total discharge per ton board of dissolved solids, BOD and COD depends mainly on the pulp yield up to a very high degree of system closing,<sup>1</sup> whereas concentrations of these substances in the effluent depend primarily on the amount of fresh water used. In mills using some form of internal recovery system for fines, e.g. a drum filter or a sloping screen, the concentration of suspended solids is however, virtually independent of the degree of recycling. Thus the discharge of suspended solids is reduced to an extent which is almost proportional to the degree of closing of the process water system.

External sedimentation of process water is common in Swedish mills. If the sediment is returned to the bottom layer pulp, however, care must first be taken to remove sand and grit, which otherwise will increase the wear on both process equipment and cutting tools.

An example of the effluents from a hardboard mill using unbarked saw mill slabs of pine and 1.1 MPa defibration pressure (gauge pressure) is given in Table 1. This mill has two separate water systems, one for process water and one for less polluted water, such as shower water. The total discharge is 13.5 m<sup>3</sup> of waste water, 51 kg of BOD and 12 kg of suspended solids per ton of board. The

Hard board production

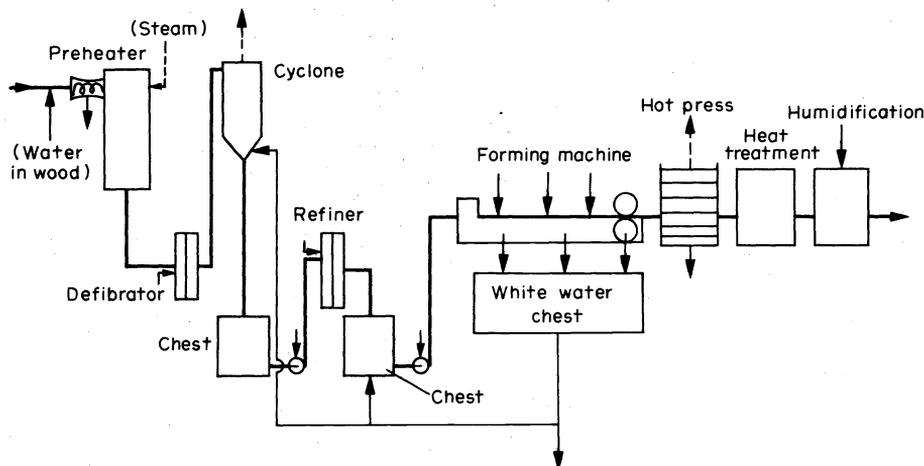


Fig. 1. The Asplund process for hardboard production.

Table 1. Example of effluents from a hardboard mill using unbarked pine wood. Defibration pressure 1.1 MPa (gauge)

Parameter	Process water	Less polluted water
Effluent (m <sup>3</sup> /ton board)	7.0	6.5
TS (g/l)†	12.7	1.5
SS (g/l)‡	1.2	0.5
COD (g/l)	14.2	1.1
BOD <sub>7</sub> (g/l)	6.8	0.5

†Total solids.

‡Suspended solids.

COD-discharge is 106 kg per ton. Such values are common before measures such as these discussed below have been introduced.

A chemical analysis of the process water from this mill is given in Fig. 2.<sup>2</sup> The striped parts of the columns indicate dissolved material with a molecular weight less than approximately 10,000–15,000 as determined by ultra-filtration. Lignin type materials make up about 17% of the total solids and carbohydrate materials about 62%. The ash content was 3, and 18% of the total solids was left uncharacterized. This part probably contains water

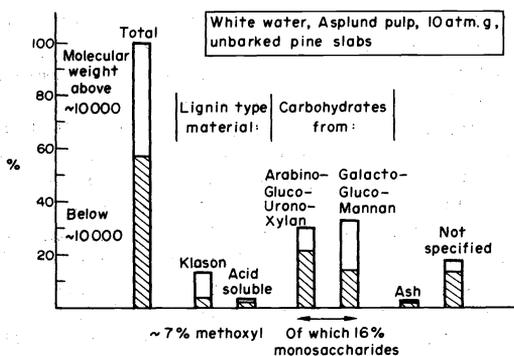


Fig. 2. The chemical composition of a white water from a hardboard mill, using unbarked saw mill slabs of pine (*Pinus silvestris*). The striped parts of the columns indicate dissolved material with a molecular weight approximately less than 10,000–15,000.<sup>2</sup>

soluble extractives, mainly from the bark, and also carbohydrates modified during the process.

Figure 3 gives the COD for different fractions of the total solids in the effluent from an insulating board mill. Not only the dissolved material but also the suspended solids apparently contribute to the total COD. The finest fraction of suspended solids had the greatest COD as calculated per gram of substance.

Among ways of reducing or solving the pollution problems, the system closure has already been mentioned. Other ways are high yield pulping, external evaporation of process water, biological and chemical treatment, and fodder yeast production using process water as substrate. These will be discussed below.

2. HIGH YIELD PULPING

A decrease in preheating time or preheating pressure will result in a higher pulp yield. The energy needed for defibration will however also increase, as illustrated in Fig. 4.<sup>3</sup>

Here, the total energy consumption for defibration and refining of a standard bottom layer pulp for hardboard is given as a function of the preheating pressure in the range 0.3–1.2 MPa (gauge pressure) with two minutes preheating time. The raw material is chips of unbarked pine logs. The figure also shows, with the axis to the right, the amounts of dissolved wood materials accompanying the pulp, the screw water leaving before the preheater, and the chip wash water.

As a result of this development work carried out on a mill scale, a number of Swedish mills have reduced their defibration pressure to approximately 0.7–0.9 MPa

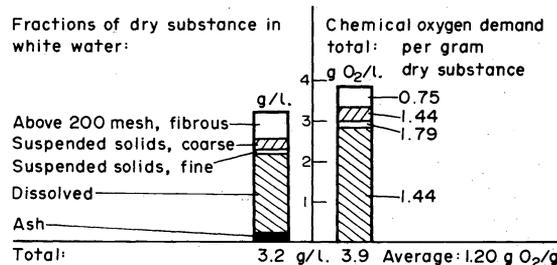


Fig. 3. COD for different fractions of the total solids in a waste water from an insulating board mill.

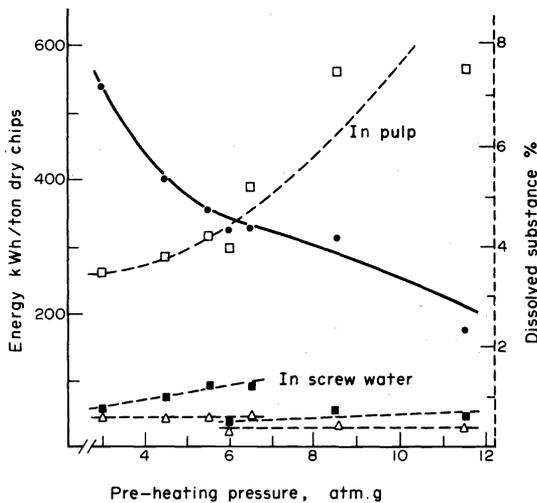


Fig. 4. The left hand ordinate and solid curve show total defibration and refining energy to produce a standard hardboard pulp from unbarked pinewood. The right hand ordinate and dashed curves show dissolved material. The preheating time is two minutes. (1 atm equals approx. 0.1 MPa).<sup>3</sup>

(gauge) after installing the necessary additional defibration equipment. As a result, the BOD-discharge has been reduced by up to 50% at a total cost of about 2 US \$ per ton of board.

Figure 5<sup>4</sup> shows the BOD-discharge as a function of preheating time for two different defibration pressures. At a gauge pressure of 0.98 MPa, an increase in preheating time from 2 to 5 min has raised the BOD in the effluent from 65 to 110 kg/ton. At the lower pressure, 0.78 MPa, the influence of the preheating time on the BOD is somewhat less marked and easier to control.

It should also be noted that the preheating time can only be kept under control if measures are taken to regulate the chip level in the preheaters sufficiently rapidly to follow variations in the production rate in the defibrator.

Figure 6<sup>4</sup> gives the BOD<sub>7</sub> and the amount of dissolved substances accompanying pulps from debarked and unbarked chips and from forest residues, mostly tops and branches from spruce.

In mill scale experiments using debarked wood instead

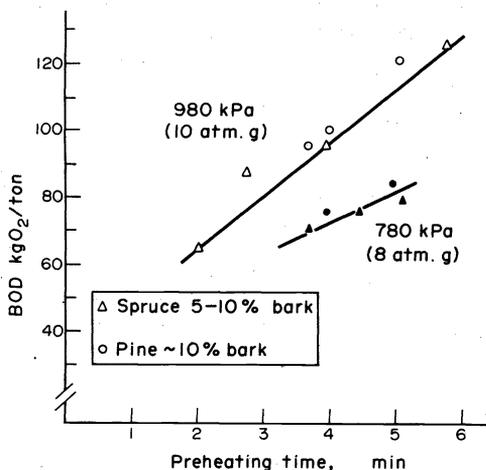


Fig. 5. BOD<sub>7</sub> as a function of preheating time at two different defibration pressures for unbarked wood from Scandinavian pine and Norwegian spruce.<sup>4</sup>

of unbarked wood, the BOD<sub>7</sub>-discharge was decreased from 86 to 55 kg/ton. No significant difference was found in this case between unbarked wood and forest residues with respect to BOD and pulp yield.

It should, however, be noted that few fiber building board mills are able to select their raw materials. From a general environmental point of view it is also important to note that the fiber building board mills utilize the waste from forestry and forest products industries, which unfortunately makes their effluent treatment more difficult and more expensive.

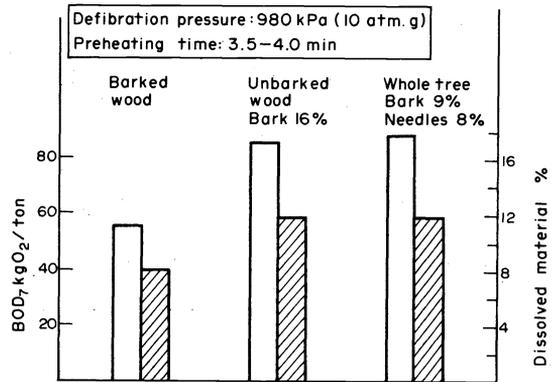


Fig. 6. BOD<sub>7</sub> and dissolved substances accompanying the pulp from three different qualities of spruce wood. Defibration pressure approx. 1.0 MPa (gauge) and preheating time 3.5–4.0 min.<sup>4</sup> (1.0 MPa equals approx 10 atm).

### 3. CLOSURE OF THE PROCESS WATER SYSTEM

A French mill producing both hardboard and insulating board has been operating without any discharge of process water for about 2 yr.<sup>5</sup> They have thus shown that under certain conditions it is possible to produce wet process fiber board without water pollution.

To what extent is this solution applicable in other fiber building board mills?

The requirement of fresh water is about the same for both hardboard and insulating board production. Insulating board, however, enters the dryer at a solids content of about 35–40%, whereas evaporation in the hot press for hardboard normally starts at a solids content of 50–60%. This means that 1.5–1.8 m<sup>3</sup> of water per ton of insulating board and 0.7–1.0 m<sup>3</sup>/ton of hardboard leaves in the form of steam. It is thus easier to close the water system in an insulating board mill, and in the U.S., in Canada and in France total system closure in insulating board mills has been reported.

One key to total system closure is a high solids content in the pulp after the cyclone of the defibrator. If the pulp solids content is raised to a higher level after the cyclone than that which normally prevails when the evaporation starts in the dryer or hot press, there will be room for some water addition.

Hitherto it has been common practice to dilute the defibrated pulp with water at the top of, or even before, the cyclone to prevent its clogging. However, in this case most of the steam accompanying the pulp will condense. If the system is redesigned to dilution of the pulp at the bottom of the cyclone instead of at the top, more steam will escape and a pulp solids content of about 50–60% and a lower stock temperature can be attained. Thus, a drop in temperature from 70 to 50°C in the process

water system is reported from a Swedish mill after installation of new cyclones.

In a totally closed mill, mechanical seals will have to be used to eliminate sealing water. Fresh water in showers can be reduced either by using intermittent high pressure showers or by reusing filtered process water. Overlay pulp produced from fresh water cannot be used if total closure is to be achieved. Even the moisture in the chips entering the mill is then important.

To operate a totally closed mill, it is vital to have sufficient buffer capacity for white water in the case of a production stop.

In a completely closed white water system the concentration of dissolved wood substances will rise to about 5–10%, depending on the pulp yield. The French mill with a concentration of about 10% dissolved solids in the white water reports no problems with the board properties other than colour. More information is, however, needed about the influence of closure on the surface properties of the board, for instance with regard to water-based paints. An increased tendency for deposition on press wires and platens and on other equipment might also become a problem.

#### 4. EXTERNAL EVAPORATION OF PROCESS WATER

To avoid the negative effects of total system closure, a lower degree of closure combined with an external evaporation of excess process water is an alternative. This is practised today by two mills in the U.S. and one mill in Sweden as well as by one mill in Germany.<sup>6</sup> The Swedish mill, with about 93% pulp yield, reaches a concentration of about 3.5% dissolved solids in the recirculating process water, partly by sectioning the water flow system, and takes 1.7 m<sup>3</sup> of process water per ton of pulp to the evaporators.<sup>7</sup> The two American mills reach about the same concentration of dissolved solids by counter current washing of a lower yield pulp after defibration.<sup>8</sup>

Instead of burning the evaporation residue, a market use as a cattle feed ingredient has developed. In the American mills the evaporation costs are now said to be paid for by such cattle feed sales. With high investment costs, however, evaporation is an attractive alternative only in mills with a minimum annual production of about 100,000 tons. The condensate from the evaporation contains about 2 kg of BOD per ton of board, depending on the raw material, and this will need some kind of treatment.

A solution suitable for an integrated building board and unbleached kraft pulp mill has been developed by one Swedish company. The process water from the hardboard mill is here used for the final countercurrent washing of the kraft pulp. Dissolved material from the building board pulp thus passes to the kraft mill evaporators.<sup>9</sup>

#### 5. FODDER YEAST PRODUCTION

In Romania, with beech wood as raw material, dissolved wood sugars are utilized for protein production. Most wet process fiber building board mills there are now connected to a fodder yeast plant. The effluent is separated by DKP-presses<sup>1</sup> to a solids content of about 2%. After acid hydrolysis, the resulting mono-sugars, with nutrients added, are used as a substrate for the *Torula utilis* yeast of about 53% of protein content. The BOD-reduction in the yeast production unit is said to be approximately 70%. About one cubic meter of water remains in the pulp after the DKP-presses, however, and

since the pulp yield is kept low (82–85%) in order to produce yeast substrate, the BOD-discharge is still rather pronounced.

The investment costs for such a fodder yeast plant are said to be approximately 50% of the costs for the fiber building board mill itself. The economy will thus depend on the prices of other fodder proteins, such as soya and fish meal, and on labour costs. During the acid hydrolysis, lignin and other dissolved wood substances tend to coagulate and produce scale on the equipment. This precipitate will have to be removed.

In a similar process, called the Symba process, developed by a Swedish company, the acid hydrolysis has been replaced by enzymatic hydrolysis by a micro-organism.<sup>10</sup> The method has been developed mainly for starch-rich effluents from the potato processing industry, but it might be interesting for fiber building board effluents as well. Research work at our laboratory concentrates on similar processes for cellulose degradation.

#### 6. BIOLOGICAL TREATMENT

A number of fiber building board mills both in the U.S. and in Europe have adopted some form of biological treatment for their effluents. Both activated sludge systems and aerated lagoons are in use and BOD-reductions of from 60 to 95% are reported.

However, most mills using biological treatment also report problems with periodical overflows of large amounts of suspended solids to the recipient. These periods occur more often during the winter time and are more pronounced in areas with cold winters. The causes are not completely understood, and it has not yet been possible to eliminate these overflows of suspended solids.

The simplest form of biological treatment is a lagoon in which the waste water is kept before discharge to the recipient. To shorten the retention time in the lagoon, aerators are normally installed, and the pH is adjusted to about 7. The nutrient requirements are less than in the activated sludge treatment, and nutrient can sometimes be omitted when such lagoons are used.

A normal load for an aerated pond is about 20–40 g BOD<sub>7</sub> per cubic meter of pond volume per day. With such a conventional BOD-load and the concentrated effluents which occur in fiber building board mills, the retention time will however be long. A waste water with 2 g BOD/l with a load of 40 g BOD/m<sup>3</sup>/day, would for instance require a retention time of 50 days. In a cold climate this will result in low, i.e. unfavourable, temperatures. Normally, temperatures below 10°C are not suitable for biological treatment.

When large amounts of waste water with a high BOD-concentration are to be treated, more intensive biological treatment methods, such as the activated sludge process, must be used. The retention time is here reduced to about four hours through a high concentration of micro-organisms in combination with intensive aeration. Nutrient addition and pH-adjustment are necessary. Activated sludge treatment of effluents from fiber building board mills in laboratory and pilot plant scale is reported to give BOD-reductions from 85<sup>11</sup> to 95%.<sup>12</sup> Other methods of interest are trickling filters in the form of towers, constructed of corrugated plastic material, and the so called RBS-method using a "rotating biological surface". In the RBS-method bacteria are grown on corrugated plastic discs, fastened to a rotating, horizontal shaft. The discs are submerged to about 40% in the effluent to be treated. The RBS-method has shown good

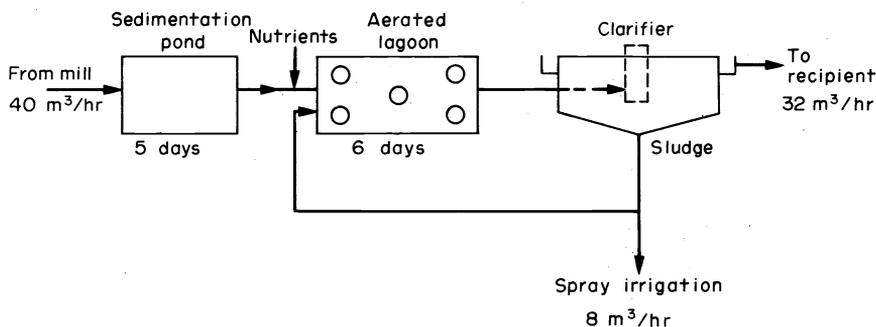


Fig. 7. Aerated lagoon with sludge recycling for fiber building board effluent.

results on a pilot plant scale for fiber building board effluent,<sup>13</sup> and one mill has decided to instal it.

A biological treatment plant for a fiber building board mill is exemplified in Fig. 7. The plant consists of a sedimentation pond, an aerated lagoon with five surface aerators, and a secondary clarifier. The presedimentation is necessary to prevent fiber sedimentation in the aerated lagoon. About 30% of the sludge from the secondary clarifier is recycled to the aerated lagoon.

The retention time in the aerated lagoon is about six days, and the "mixed liquid suspended solids" (MLSS) is 3.5 g/l. The BOD-load is approximately 500 g of BOD/m<sup>3</sup>/day, which is ten times that of a conventional aerated lagoon. This plant can be considered as a hybrid between an activated sludge and an aerated lagoon treatment.

Analyses of the effluent leaving the mill and after the secondary clarifier are given in Table 2. The BOD-reduction varies between 85 and 99%, and the COD-reduction between 70 and 92%. The reduction in suspended solids is however quite unsatisfactory during the winter period, even though this mill is located in an area with winter temperatures just around 0°C.

The total costs for the treatment are said to be approximately U.S. \$ 3.50 per ton board, including disposal of the excess biological sludge by spray irrigation.

In most mills the biological sludge is dumped as land fill. A Belgian mill, however, returns the biological sludge from an activated sludge treatment to the hardboard production. About 4%, calculated as dry sludge on dry pulp, is said to give no problems. The effect of biological sludge on internal bonding in hardboard was, in laboratory control experiments, shown to be negligible.<sup>14</sup>

7. CHEMICAL TREATMENT

Chemical treatment is the best method for reduction of suspended solids in process water. For this purpose polyelectrolytes are often most efficient.

Addition of a combination of lime followed by aluminium sulphate to a pH value of about 4 reduces the COD by

Table 2. Analyses of waste water from a fiber building board mill before and after biological treatment in an aerated pond

Period	BOD <sub>5</sub> (g/l)		COD (g/l)		SS† (g/l)	
	(in)	(out)	(in)	(out)	(in)	(out)
Summer	3.4	0.09	7.4	0.6	0.40	0.20
Winter	4.4	0.5	7.5	2.2	0.50	1.40
Year average	3.9	0.3	7.5	1.4	0.45	0.80

†Suspended solids.

35–40%, and the BOD by maybe 25–30%.<sup>15</sup> Mill scale studies in two Swedish mills have however shown that the return of this chemical sludge to hardboard production has a negative effect on the board strength properties,<sup>16</sup> as is shown for internal bonding in Fig. 8. Since chemical costs are about U.S. \$2.5 per ton of board, additional costs for separate sludge treatment may make the method less attractive.

One U.S. mill reports that the addition of a cationic polymer directly to the pulp before it reaches the forming machine markedly increases the retention of both colloidal and fibrous materials. A 50% BOD-reduction is reported. Since the chemical is added directly to the pulp no external sludge treatment is needed. The polymer addition is said to have no negative effect on the hardboard quality.

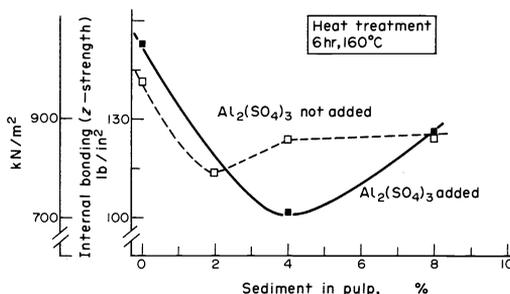


Fig. 8. Internal bonding for laboratory made hardboards as a function of the amount of chemical sludge in the pulp, calculated as dry sludge on dry pulp. The hardboards were made with and without addition of aluminium sulphate.

8. CONCLUSIONS

It is difficult to give general recommendations as to the best water pollution treatments for the fiber building board industry. A combination of two or more of the methods discussed above might be the best alternative.

For a large size mill, system closure combined with external evaporation of some process water seems to be the most economical procedure.

Total system closure might be the best alternative for insulating board mills, provided that surface problems in painting can be eliminated. Dissolved solids could be reduced by a high yield pulping, achieved either by process modifications or by selected raw material.

Generally, a high yield pulping will also reduce the costs of biological treatment, which will probably be the best alternative for smaller mills.

Another possibility is to integrate some form of water treatment into the water system. A continuous

chemical coagulation of suspended and colloidal substances will eliminate some of the problems in system closure. One U.S. mill is reported to have closed the waste water system over a biological treatment plant. In this case, however, the system is not totally closed since the excess biological sludge is disposed of by spray irrigation.

Naturally, a knowledge of future standards is important when selecting the best treatment method. Will there be a definite demand for zero pollution, which seems to be the case in the U.S.? Or will there be a system of payment for pollution as suggested in some European countries? It is also important to consider which analytical method the standards are based upon, since a reduction in BOD is not equivalent to a reduction in COD.

#### REFERENCES

- <sup>1</sup>G. Gran, *Pure Appl. Chem.* **29**, 299 (1972).
- <sup>2</sup>M. Björklund Jansson and E. L. Back, *Wood Sci.* (1975). In press.
- <sup>3</sup>E. L. Back and S. A. Larsson, *Svensk Papperstid.* **75**, 723 (1972).
- <sup>4</sup>K. Helge, *Papirindustriens Forskningsinstitut, Teknisk information nr 6* (1974).
- <sup>5</sup>Pollution et Nuisances No. 47 (11 Mai 1973) and B. Maréchal, personal communications.
- <sup>6</sup>Patent (Auslegeschrift) 2 062 952, Germany 1974 (W. Holzhäuer Atex Werke K. G.).
- <sup>7</sup>L. Sohlman, *Svensk Papperstid.* **71**, 599 (1968).
- <sup>8</sup>J. E. Leker, *Southern Pulp Paper M.* **36**(1), 32 (1973).
- <sup>9</sup>B. Fagerlund, *IUPAC Int. Congress of Industrial Waste Waters and Wastes*, Stockholm (1970). Reprint Fri. II 4.
- <sup>10</sup>*Modern Kemi* (4) 33 (1974).
- <sup>11</sup>J. Rennerfelt, *Svensk Papperstid.* **68**, 53 (1965).
- <sup>12</sup>E. Dewes, A. Denne and H. Meyers, *Wasser Luft Betrieb* **10**(5), 2 (1966).
- <sup>13</sup>D. J. Bennet, T. Needham and R. E. Summer, *Tappi* **56**, 182 (1973).
- <sup>14</sup>Swedish Forest Products Research Laboratory, Unpublished data.
- <sup>15</sup>C. Bäck and M. Björklund Jansson, *Medd. Svenska Träforskningsinst. Serie B*, 306 (1975).
- <sup>16</sup>C. Bäck, *Medd. Svenska Träforskningsinst. Serie B*, 305 (1975).