

## Effects on Pulp Properties of Magnesium Hydroxide in Peroxide Bleaching

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High alkalinity in peroxide bleaching has traditionally been achieved using sodium hydroxide and sodium silicate. In the present work, partial and total substitution of traditional sodium-based peroxide bleaching auxiliary chemicals with a highly pure magnesium hydroxide-based bleaching additive was studied on two high-brightness mechanical pulp types from Norwegian spruce (*Picea abies*): pressure groundwood and thermomechanical pulp. Peroxide bleaching with 3.0% charge was carried out on both pulps to a given brightness level. The bleached pulp was studied with respect to electrical conductivity, zeta potential, and water retention value. The bleaching filtrate was measured for total organic carbon content, biological and chemical oxygen demand, cationic demand, extractives content, and turbidity. The main results from this study were that the cationic demand and electrical conductivity of the bleaching filtrate were significantly lowered for both pulps when a magnesium-based bleaching process was used. At the same time, the zeta potential of the dilute pulp suspension was only slightly affected. Magnesium hydroxide-based peroxide bleaching seems to increase the water retention value of the pulp, especially on fines-rich pressure groundwood, predicting a good strength potential of the pulp. The bleaching filtrate from the magnesium hydroxide-based process was significantly cleaner in all categories measured, which indicates that this is an environmentally sound concept.

*Keywords:* Peroxide bleaching; Bleaching effluent; Magnesium hydroxide; Pulp properties

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### INTRODUCTION

High brightness pulp is very important for printing papers and packaging. To achieve an efficient and sustainable bleaching sequence, hydrogen peroxide has become dominant in mechanical pulp bleaching in Northern and Central Europe. On the downside, the use of peroxide requires highly alkaline conditions in the bleaching stage, and this leads to high environmental loads and interferes with papermaking.

Chemical (kraft) pulping is the dominant process for producing fibers for several paper grades, but due to requirements of high opacity and low basis weight, the use of a large amount of mechanical fibers is still necessary. This requires highly optimized bleaching sequences in order to have a process that is environmentally sustainable. One solution is to replace NaOH with Mg(OH)<sub>2</sub> in peroxide bleaching (Pykäläinen *et al.* 1993; Dionne *et al.* 1993; Soteland *et al.* 1988). Previous studies have shown the environmental benefits of using magnesium hydroxide on mixed wood species typical in North America

(Dionne *et al.* 1993, He *et al.* 2004; 2006, Ni and He 2010), but these differ from the conditions faced in Europe.

Anionic colloidal and dissolved compounds released in the pulping and bleaching stages are carried over to the papermaking process together with the pulp. The release and effects of these anionic loads have been studied by Thornton *et al.* (1991; 1993), He *et al.* (2004, 2006), and Dunham *et al.* (2002). Thornton *et al.* reported that galactoglucomannans are deacetylated and adsorbed on fibers during alkaline peroxide bleaching (1991). Using a similar, thermomechanical pulp and 3.0% peroxide dose with the traditional additives, they also found that bleaching tripled the cationic demand of a dilute (1% consistency) pulp sample. A quarter of this cationic demand of bleached pulp was attributed to dissolved and colloidal substances. Another major source of “anionic trash” was polygalacturonic acids released from TMP in the alkaline peroxide bleaching (Thornton *et al.* 1993). The dissolved and colloidal substances in peroxide-bleached mechanical pulp have been shown to interfere with flocculation induced with cationic polyacrylamide and hinder web drainage (Dunham *et al.* 2002). It has also been revealed that replacing traditional sodium-based chemicals in the peroxide bleaching of TMP with magnesium hydroxide has positive effects, reducing anionic trash levels and improving the retention of calcium carbonate filler. For example, it was reported that the amount of anionic trash was reduced by 30 to 40% on a constant silicate dose, depending on the peroxide charge used, ranging from 1% to 3% on the dry pulp mass (He *et al.* 2006).

In a North American study it was concluded that when magnesium hydroxide was used, the electrical conductivity of the bleaching filtrate was significantly reduced and the chemical oxygen demand (COD) was reduced by 20 to 35% for a given peroxide charge. They also found that the brightness was not affected by the change in alkali (He *et al.* 2004). Further results concerning the environmental load have been published. Knecht (2007) reported a 30% reduction in the COD load from peroxide bleaching stage with a high 5.0% charge and 4 h bleaching time. In addition, a Canadian study published in 2010 reported a 35% reduction in COD and a 52% in BOD<sub>5</sub> but with a 1.4%-ISO loss in brightness on a mixed balsam and fir TMP furnish (Leduc *et al.* 2010). Kong *et al.* (2009) partially replaced sodium-based chemicals with magnesium hydroxide in the bleaching of aspen CTMP. They reported a slight brightness loss, a large amount of residual peroxide, and improved bulk and yield. There is also a well-documented case of a full mill-scale conversion of a tower-bleaching sequence by Irving Paper in Saint John, Canada in 2003. In addition to the lower bleaching costs, the COD in the effluent water and the anionic trash from the bleaching stage were also reduced (Li *et al.* 2005). However, in all the previous studies that have dealt with magnesium hydroxide in peroxide bleaching, the initial ISO brightness of pulp was below 60% and usually the pulp was of mixed wood species, making a comparison with North European conditions difficult. In addition, the earlier experiments have relied on direct mass-based replacement of mono-valent sodium hydroxide with di-valent magnesium hydroxide and usually a high, constant dosing of sodium silicate.

He *et al.* (2006) studied the development of the water retention value (WRV) in spruce PGW when magnesium-based bleaching was applied. One of their findings was that in pulp bleached using a high alkali dose (3.0%) and acidified to pH of 4.5, the NaOH alkali produced 2.8 g/g water retention, some 7% higher than in pulp bleached using Mg(OH)<sub>2</sub>. This situation was reversed when a smaller amount, 2.0% of either alkali was used. Since usually only 1 to 2% of bleaching alkali on dry pulp by weight is used

even during high-brightness bleaching, the water retention in this range and near neutral pH is of a special interest.

The reaction kinetics of magnesium-based bleaching have been described by Ni *et al.* (2010). Compared to a conventional NaOH-based process, magnesium-based bleaching reaction had a lower rate constant and a higher activation energy, which resulted in slower bleaching and in higher temperature dependency. They also concluded that magnesium-based bleaching was more affected by the peroxide concentration but was less sensitive to variations in pH. Despite earlier research there is still a lack of understanding of the effects of  $\text{Mg}(\text{OH})_2$  on fiber and pulp properties under conditions and on doses similar to the industrial bleaching process.

Peroxide bleaching is highly sensitive to the detrimental effects of transition metal ions, and their effects have been widely reported (Gupta 1970; Colodette and Dence 1989; Ghosh and Ni 1998). Manganese ions hinder the bleaching result mostly by catalyzing peroxide's direct decomposition reaction to water and oxygen (Wekesa and Ni 2001). Iron and to a smaller extent copper are detrimental primarily since they cause discoloration in the pulp (Gupta 1970; Wekesa and Ni 2001). Unlike iron or copper, manganese can easily be removed from the process in a pre-bleaching chelation stage. Unpurified grades of magnesium hydroxide and magnesium oxide usually contain thousands of ppm of iron (del Valle-Zermeno *et al.* 2012) and manganese more than 50 ppm (van der Merwe *et al.* 2004), making these industrially produced low-purity magnesium hydroxide and magnesium oxide grades unsuitable for high-brightness bleaching applications. One earlier North American study of an industrial-scale refiner bleaching included a specification of the purity of the magnesium hydroxide used. The maximum metals content was: iron 0.10%, manganese 120 ppm, and copper 10 ppm (Harrison *et al.* 2008). In that mill trial however, the target brightness range was low, from 52 to 72% (ISO). By comparison to this, the magnesium hydroxide-based additive used in the present study was of a significantly higher purity, containing only some 5 to 10% of Fe and Mn when calculated from the maximum concentrations. By introducing magnesium hydroxide to a bleaching stage,  $\text{Mg}^{2+}$ -ions are carried not only to papermaking with the pulp but also to preceding process stages: pulping, thickening, and chelation stages. As found by Süss *et al.* (2002), the  $\text{Mg}^{2+}$ -ions hinder the chelation of detrimental metal ions by their thousands-fold concentration. However, this is problematic only if much greater amounts of Fe and Mn are introduced into the system, possibly as impurities in a low-grade magnesium hydroxide.

The aim of the present study was to gain systematic knowledge on the effect of replacing sodium hydroxide with magnesium hydroxide on bleaching efficiency and pulp properties. A further objective was that this understanding would enable a quick mill-scale implementation of the magnesium hydroxide-based bleaching concept. The experiments were carried out on pressure groundwood (PGW) and thermo-mechanical pulp (TMP) of high initial brightness under the conditions typically found in mills in Northern Europe. Traditional sodium-based bleaching agents were gradually replaced with a high-purity  $\text{Mg}(\text{OH})_2$ -based additive. The bleached fiber suspensions were then studied in terms of charge, dewatering, and electrokinetic properties. In addition, the effect of  $\text{Mg}(\text{OH})_2$ -based additive on the environmental impact of bleaching was assessed.

## EXPERIMENTAL

### Materials

To fully capture the effects of magnesium-based bleaching alkali, the raw materials and bleaching conditions were set to closely match the situation in a pulp mill. Laboratory-scale peroxide bleaching experiments were carried out on two pulps, a thermomechanical pulp (TMP) and pressurized groundwood (PGW) from Norway spruce (*Picea abies*), which were supplied by Finnish pulp mills. The pulp samples were unbleached, mill-chelated, and drawn from the bleach press. De-ionized water was used in the experiments. All chemicals used in bleaching and analyses were of *pro analysis* grade, except for the commercially available bleaching agent based on fortified hydrated magnesia of extremely high purity supplied by BIM Kemi AB. The bleaching additive contained detrimental impurities: iron less than 10 ppm, manganese less than 5 ppm, and copper less than 1 ppm. For comparison, the transition metal contents of some unpurified magnesium hydroxide grades were tested. The mined grades of magnesium hydroxide contained 50 to 100 times more Fe and 10 to 20 times more Mn, whereas magnesium hydroxide extracted from seawater contained 30 times more Fe and 10 times more Mn than the additive used in these experiments. Chemical dosing of the additive was calculated on a dry pulp mass basis. The magnesium hydroxide dose was calculated using the manufacturer's instructions, where one kilogram of sodium hydroxide was replaced by 0.52 kg of the magnesium hydroxide product. Sodium silicate dosing was calculated in direct relation to the amount of NaOH employed, but with a minimum dose of 0.5% on the dry pulp. Four different experimental points were thus obtained, as shown in Table 1.

**Table 1.** Alkali and Sodium Silicate Doses and Replacement Ratios Used in Bleaching Experiments

Experimental point	NaOH portion of total alkali mass (%)	Mg(OH) <sub>2</sub> portion of total alkali mass (%)	NaOH dose (m-%) on dry pulp	Mg(OH) <sub>2</sub> dose (m-%) on dry pulp	Na <sub>2</sub> SiO <sub>3</sub> dose (m-%) on dry pulp
1	100	0	2,1	0,0	1,0
2	70	30	1,5	0,5	0,7
3	40	60	0,8	0,7	0,5
4	0	100	0,0	1,1	0,5
5	100	0	2,1	0,0	1,0
6	0	100	0,0	1,1	0,5

### Methods

The experimental bleaching conditions were: 3.0% hydrogen peroxide, 20% (points 1-4) or 25% (points 5 and 6) consistency, and 60 °C for 180 min. Pulp and chemicals were thoroughly mixed using an Erweka AR 402 Z-arm kneader, after which the pulp sample was sealed in a plastic bag, which in turn was placed in a thermostated water bath. The bleaching was followed by dilution to 5% consistency using ion-exchanged water and mixing. The pulp pH was adjusted with dilute sulfuric acid to a value of 6.7 according to a Metrohm 744-meter. The pulp zeta potential was measured using a Müttek SZP 06 instrument and the electrical conductivity with a Knick 702 instrument. The water retention was measured in accordance to SCAN C 62:00, but with

a lower centrifugation of 2000  $g_n$ . Fines content was measured optically using a Lorentzen & Wettre Fiber Tester 912 and TAPPI method T 271. The transition metal contents were measured with atomic absorption spectrometry according to ISO 11885.

The dilute pulp was filtered on a Büchner funnel through a VWR 413 paper with a medium pore size of 4 to 7  $\mu m$  for subsequent analyses of the filtrate and the pulp. The following measurements were carried out on the filtrate: the amount of residual peroxide by iodometric titration in accordance to KCL 214:85 method, and the cationic demand by polyelectrolyte titration with Mettler DL25 automated titrator and Müttek PCD 02 device using (0.001 N) poly-diallyl-dimethyl-ammonium chloride (poly-DADMAC) by BTG as the cationic polymer.

Additional experiments and analyses were carried out on the filtrates from 100% NaOH-based or 100%  $Mg(OH)_2$ -based bleaching PGW. The total organic carbon content (TOC) was measured with a Shimadzu TOC 5050 analyzer, the chemical oxygen demand (COD) in accordance to SFS 3020, the biological oxygen demand ( $BOD_7$ ) in accordance to SFS EN 25814, and the turbidity was measured using a Hach 2100AN IS photometer. The extractives content was determined by gas chromatography with a HP 5890 II+ device, HP 7673 injector and HP-1 column. Samples were prepared by pH-adjustment, MBTE-extraction, evaporation and silanization as described by Örså and Holmbom (1994). The molecular weight distribution of dissolved organic compounds was determined by size-exclusion chromatography using a 0.45  $\mu m$  filter at a detection wavelength of 280 nm.

Pulp discs were wet-pressed under a pressure of 400 kPa for five minutes, drum-dried, and conditioned according to SCAN P 2:75. Pulp brightness was determined on these discs using an L&W Elrepho Autoline 300 spectrophotometer according to ISO 2470. An outline of the experimental procedure is given as Fig. 1.

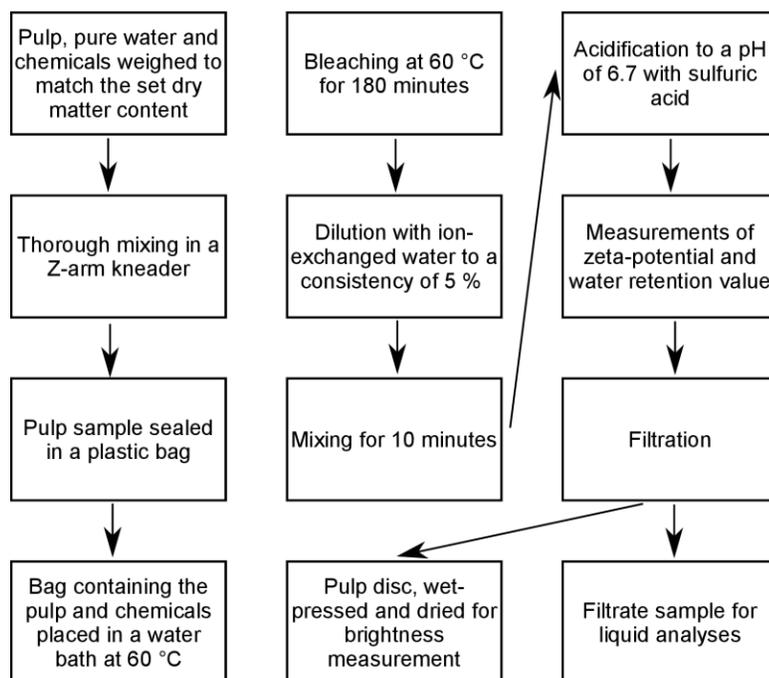


Fig. 1. A flow chart of the bleaching experiment procedure

## RESULTS AND DISCUSSION

The bleaching results and the amounts of residual hydrogen peroxide are shown in Tables 2 and 3. The choice of bleaching alkali had only a slight effect on pulp brightness (the differences were within error limits) but it had a significant effect on the amount of residual peroxide in the bleaching effluent. The proportion of residual peroxide increased from 30% to about 53% when the bleaching alkali was changed from fully sodium-based to fully magnesium-based. It is possible to utilize this residual peroxide to improve the brightness through a medium consistency pre-bleaching stage by rearrangement of the water circulations in a pulp mill (Tamper 2009) or to use the residual peroxide as a biocide in the paper mill water circulation loops and prevent harmful slime growth.

**Table 2.** The Effect of the Ratio of Magnesium Hydroxide to Sodium Hydroxide Alkali on the Final Brightness of Bleached Pulp and the Amount of Residual Peroxide

Experimental Number	1		2		3		4	
Bleaching alkali	100%NaOH		70%NaOH		40%NaOH		0%NaOH	
	0%Mg(OH) <sub>2</sub>		30%Mg(OH) <sub>2</sub>		60%Mg(OH) <sub>2</sub>		100%Mg(OH) <sub>2</sub>	
Pulp type	PGW	TMP	PGW	TMP	PGW	TMP	PGW	TMP
Final ISO-brightness (%) <sup>*</sup>	79.9±0.5	75.3 ± 0.4	79.3±0.5	75.6±0.4	79.5±0.4	75.2±0.2	78.8±0.3	75.0±0.3
Residual peroxide (g/l)	0.57	0.75	0.63	0.77	0.87	0.92	0.93	0.99
Residual peroxide (%)	30%	40%	33%	41%	46%	49%	49%	53%
Diluted pulp pH	6.9	6.8	6.8	6.6	6.7	6.7	6.5	6.8

\* Error value represents the standard deviation (n=10)

Conditions: Hydrogen Peroxide Dose 3.0%, Temperature 60°C, Consistency 20% and Time 180 min. Initial ISO Brightness Was 65.3% for PGW and 64.5% for TMP.

### Pressure Groundwood Bleaching Filtrate Properties

The filtrate from the peroxide bleaching stage was tested for TOC, COD, and BOD<sub>7</sub>. Table 3 shows that at a given pulp brightness gain and level, magnesium hydroxide led to significantly lower BOD<sub>7</sub>, TOC, and COD values. It is evident from Table 3 that magnesium hydroxide reduced the extractives content of the effluent by 66% when compared with the sodium-based bleaching process. The greatest reduction was observed for fatty acid and stearyl ester groups, at 63% and 70%, respectively.

It has been suggested in previous studies that less anionic trash is due to weak alkalinity of magnesium hydroxide. Using a constant, high (2.6%, Bé 40) dose of sodium silicate in bleaching, the use of magnesium hydroxide instead of sodium hydroxide led to less dissolution of anionic hemicelluloses, pectic acids, oxidized lignin, and resin fatty acids (He *et al.* 2008). This suggestion was supported by the data in Table 3, which show a distinct reduction in fatty acid, rosin acid, and stearyl ester groups. It has been reported that Mg<sup>2+</sup>-ions reduce anionic trash by binding with polygalacturonic acids, oxidized lignin and resin acids, neutralizing their anionic charge, and causing their deposition (He

*et al.* 2004; Ni and He 2010). They estimated that the  $Mg^{2+}$ -ions would be responsible for 15% of the total lowering of anionic trash (He *et al.* 2004).

A substantial reduction in dissolved organic material was also observed from the 65% lower turbidity, which was similar to the relative reduction in the extractives content. These results were interesting considering the political desire in Europe for a change towards a physically defined environmental taxation (Georgescu *et al.* 2010), based on *e.g.* the COD-content in the effluent. The results presented here are consistent with previous results concerning the effect of a conventional  $Mg(OH)_2$  solution on the reduction of COD bleach effluent load (Pykäläinen *et al.* 1993; He *et al.* 2004; Kong *et al.* 2009; Hu and Zhang 2009) and of effluent turbidity (Hu and Zhang 2009).

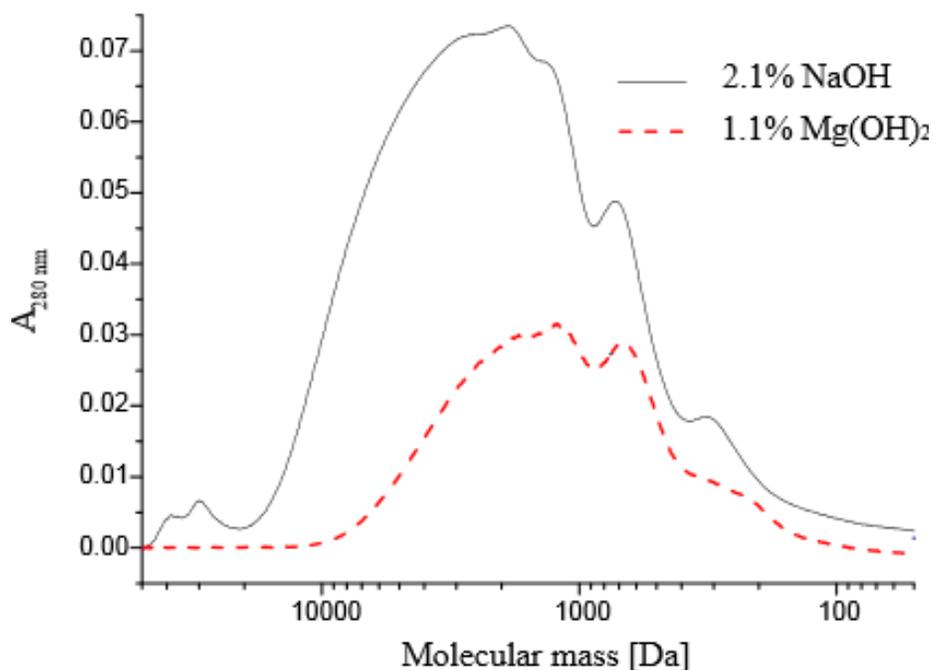
**Table 3.** The Effect of Alkali Type in Peroxide Bleaching on Filtrate Properties.

Experimental Number	5	6
Alkali type	100% NaOH	100% $Mg(OH)_2$
Final ISO brightness (%)	78.9	79.0
Amount of residual peroxide (g/L)	0.83	1.04
Residual peroxide (% Applied Amt.)	44%	55%
Initial pulp pH	10.9	9.6
Pulp pH after bleaching	8.3	8.1
Total organic carbon content (mg/L)	875	452
Chemical oxygen demand (mg/L)	3740	2810
Biological oxygen demand (mg/L)	950	525
Turbidity (FAU)	289	106
Total extractives content (mg/g)	93.3	31.3
Fatty acids (mg/mL)*	13.4 ± 0.6	5.0 ± 0.2
Rosin acids (mg/mL)*	15.9 ± 0.3	10.0 ± 0.0
Lignans (mg/mL)*	1.1 ± 0.1	0.4 ± 0.1
Sitosterols (mg/mL)*	2.9 ± 0.5	0.8 ± 0.0
Stearyl esters (mg/mL)*	19.3 ± 0.2	5.7 ± 0.3
Triglycerides (mg/mL)*	40.6 ± 0.9	9.3 ± 0.6
Total extractives (mg/mL)*	93.3 ± 2.5	31.3 ± 0.7
Molecular mass of dissolved organic compounds $\overline{M}_w$ (Da)	3460	1680

\* Absolute difference between two parallel measurements

Conditions: Hydrogen Peroxide Dose 3.0%, Temperature 60 °C, Consistency 25% and Time 180 min. PGW Pulp with Initial ISO Brightness 65.2%.

The effect of the bleaching alkali type on the molecular mass of the dissolved organic compounds was determined by size-exclusion chromatography, and the result is presented in Fig. 2. It seems that the NaOH-based bleaching resulted in not only a greater amount of dissolved organic compounds in bleaching filtrate, but also clearly bigger molecules being dissolved from the pulp. This is supported by the measured mean of molecular weight of dissolved organic compounds presented in Table 3.

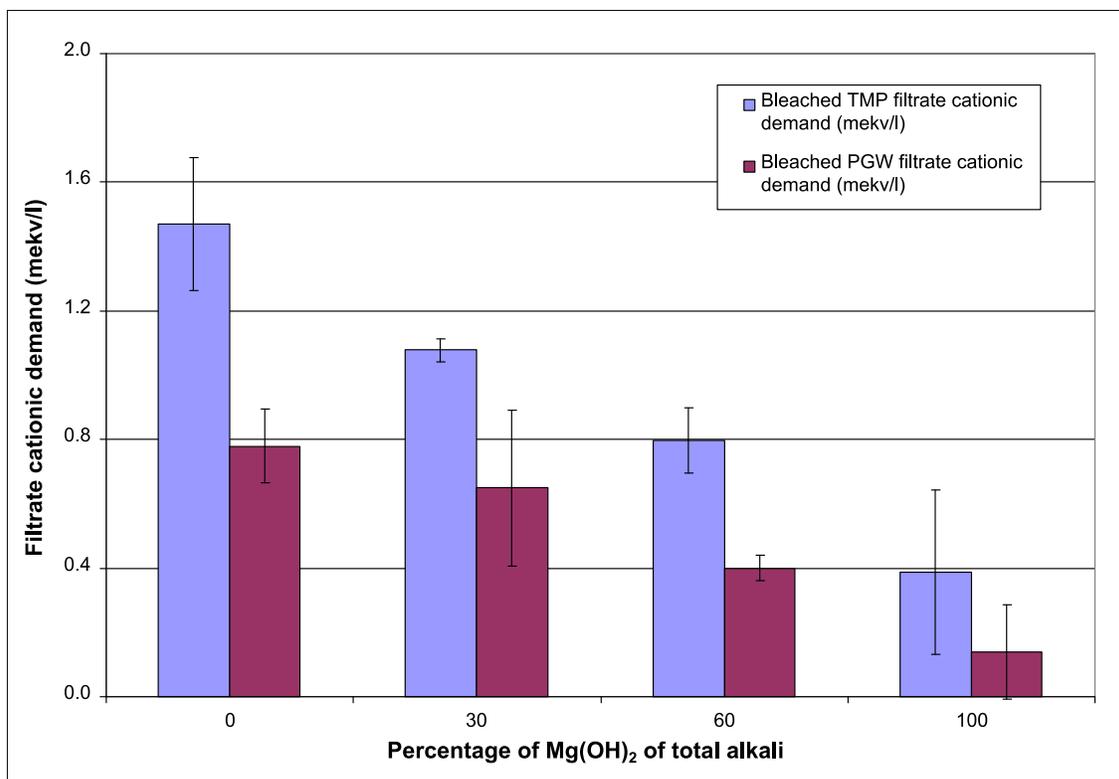


**Fig. 2.** The effect of bleaching alkali type on the molecular mass distribution of dissolved organic compounds in bleached pulp filtrate. Conditions: hydrogen peroxide dose 3.0%, temperature 60 °C and bleaching time 180 min.

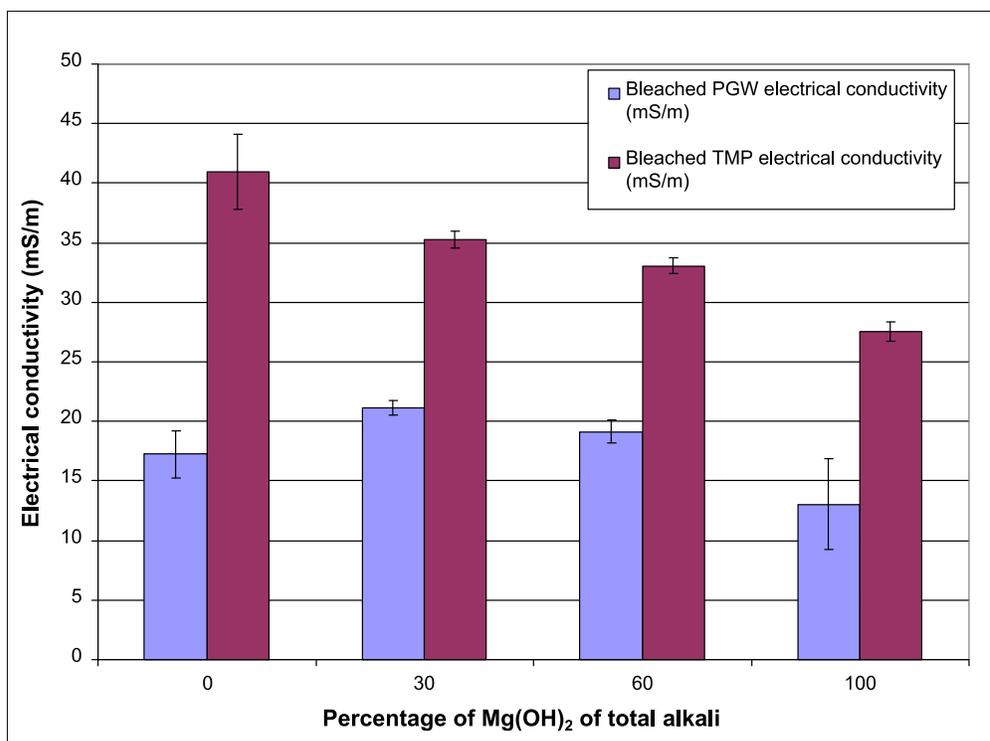
The effect of adding magnesium hydroxide in the bleaching on the cationic demand of the bleaching filtrate is shown in Fig. 3. When sodium-based chemicals were replaced with magnesium hydroxide, the cationic demand of the water filtrate was reduced by 70 to 80% for both PGW and TMP pulp types. Although the filtrate contains much less extractives when utilizing 100%  $\text{Mg}(\text{OH})_2$ , this probably cannot solely explain the reduction in cationic demand. These results are in agreement with the previously published data, which suggests a higher wire retention or less need for cationic fixatives in the papermaking process in order to maintain a given retention at the forming section (He *et al.* 2006; Hu and Zhang 2009).

### Properties of Bleached Pressure Groundwood and Thermomechanical Pulp

The effects of alkali type on the electrical conductivity and zeta potential of a dilute pulp suspension were determined after bleaching, dilution and neutralization with sulfuric acid to a pH value of 6.7. Figure 4 shows that by using magnesium hydroxide, the electrical conductivity of bleaching filtrate of TMP was reduced by 30%, a result in agreement with previous results (Hu and Zhang 2009, He *et al.* 2004). The effect was not so pronounced with PGW pulp, perhaps because of the low initial conductivity value.



**Fig. 3.** The effect of magnesium hydroxide dosing on the cationic demand of bleaching filtrate. Conditions: hydrogen peroxide dose 3.0%, temperature 60 °C and bleaching time 180 min.

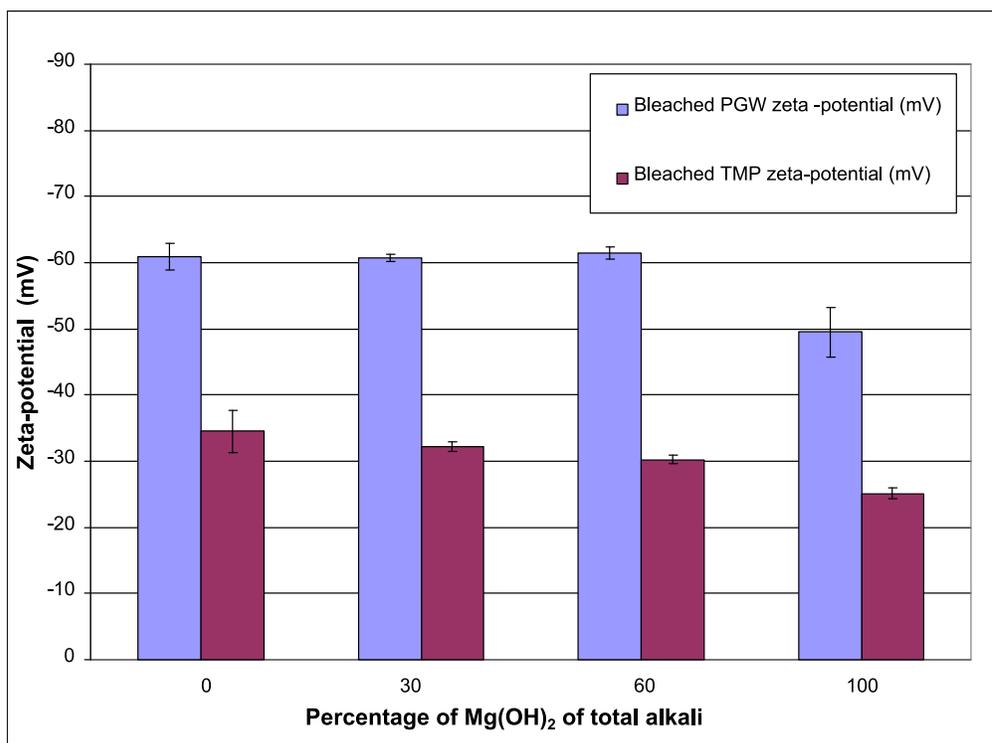


**Fig. 4.** The effect of magnesium hydroxide dosed in bleaching on the electrical conductivity of the dilute pulp. Conditions: hydrogen peroxide dose 3.0%, temperature 60 °C and bleaching time 180 min. Measured at 23 °C for a 5% pulp consistency. Error bars represent 90% confidence interval.

Figure 5 shows the effect of the bleaching alkali composition on the zeta potential of a dilute pulp suspension after being neutralized to a pH value of 6.7 after the alkaline bleaching. Despite the large amount of dissolved extractives in the PGW and a large reduction in cationic demand of the bleaching filtrate when changing from sodium-based to magnesium-based alkali, no significant changes in zeta potential were seen, suggesting that the fiber charge remained mostly unchanged.

In the case of TMP pulp treated with 100%  $\text{Mg}(\text{OH})_2$  alkali, the zeta potential value was -25 mV. For all the bleached PGW pulp samples, the zeta potential value was lower than -50 mV, reflecting a more anionic cellulosic surface. The more anionic charge of the PGW was ascribed to the surface composition of the pulp fiber, particularly to the higher degree of fibrillation in PGW than in TMP.

While extractives can cover 15 to 30% of the fiber surface, washing of the pulp might greatly affect the actual amount of extractives on mechanical pulps (Koljonen 2004). It has been reported that peroxide bleaching of TMP did not significantly reduce the amount of lignin on the fiber surface and that the charges of TMP and PGW fibers were similar after alkaline peroxide bleaching (Koljonen *et al.* 2004). This was not the case in the present study. Although in both TMP and PGW the fibers should preferably separate between the S1 and S2 layers (Franzén 1986; Salmén and Pettersson 1995), there may be some differences in the amounts of hemicelluloses, and also in the raw material composition, particularly in the submicron structure of the fibers.



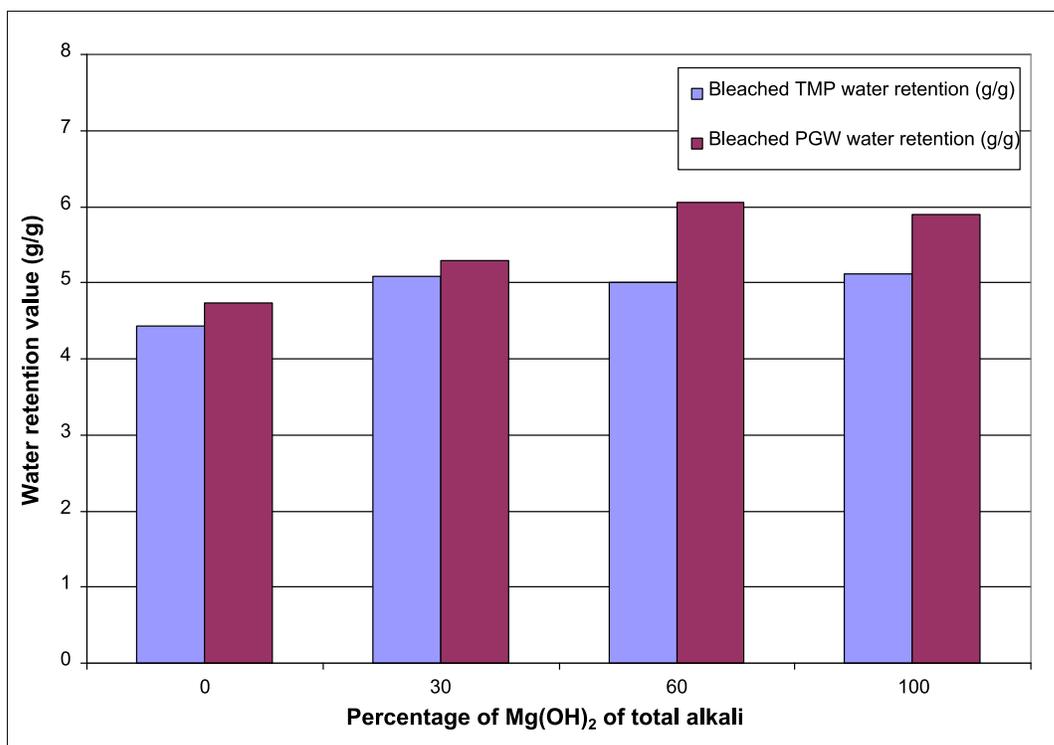
**Fig. 5.** The effect of magnesium hydroxide dosed in bleaching on the zeta potential of dilute pulp sample. Conditions: hydrogen peroxide dose 3.0%, temperature 60 °C and bleaching time 180 min. Measured at 23 °C on a 5% consistency pulp sample.

Figure 6 shows that the water retention value of PGW clearly increased, but that the water retention of TMP was only slightly affected, when bleaching was carried out using magnesium-based alkali. The higher water retention and higher sensitivity of PGW

to alkali change may be a result of its high fines content (30%) compared to TMP (13%). All the water retention values were high due to technical limitations of the test equipment. Besides a remarkable difference in amount of fines, the WRV was sensitive to differences in charge properties of the fibers.

Previous studies have claimed that multivalent cations have a tendency to bond with acidic groups in fibers and decrease fiber swelling (He *et al.* 2006), especially under neutral pH conditions. In contrast to this, a relationship between high doses of magnesium hydroxide and low pulp WRV after peroxide bleaching had been established in a study by Hu *et al.* (2009) on low-brightness aspen chemi-thermomechanical pulp. It is evident from Fig. 5 that even slightly acidic conditions, together with a moderate 1.1-2.1% dose of alkali, led to higher water retention values for pulps when magnesium hydroxide was used. This effect was more pronounced on PGW, where the water retention increased by about 20% from 100% NaOH to 100% Mg(OH)<sub>2</sub>. This difference may be the result of the high 30% fines content of PGW compared to 13% fines content of TMP. A previous study reported similar high water retention values, but only at the low end of alkali doses in bleaching and in the acidified pulp (He *et al.* 2006).

The WRV of thermomechanical pulp, containing fewer fines than PGW, seems to have been less affected by alkali change, as shown in Fig. 6. In papermaking, low water retention is often desired for easy drainage of the web in the forming section, leading to cost savings in subsequent web drying. On the other hand, high WRV has been considered to be an indication of a high bonding potential in the pulp, leading to high tensile strength in paper (Zanuttini and Marzocchi 2003). These results suggested that the tensile strength might be increased in paper made from pulp bleached using magnesium-based alkali.



**Fig. 6.** The effect of magnesium hydroxide dosing in bleaching on the water retention value (WRV) of dilute pulp sample. Conditions: hydrogen peroxide dose 3.0%, temperature 60 °C and bleaching time 180 min. Measured at 20 °C and pH 6.7 on a 5% consistency pulp sample.

## CONCLUSIONS

1. This study demonstrated that a high-purity magnesium hydroxide-based additive can be used to replace NaOH either partially or totally in peroxide bleaching in terms of pulp brightness for both PGW and TMP.
2. The magnesium hydroxide-charged bleaching resulted in a substantial reduction in cationic demand of the pulp suspensions. Increased water retention of bleached PGW indicates high retention of fines and predicts a good strength potential of the pulp.
3. The cleanliness of the magnesium hydroxide-based bleaching was reflected in the low electrical conductivity of the pulp filtrate. This, together with a low amount of extractives, dissolved and colloidal substances, indicates good runnability in papermaking.
4. It was demonstrated that the magnesium-based bleaching alkali concept has a significant environmental benefit through a reduction in TOC, COD, and BOD<sub>7</sub> of bleaching effluent, which encourages further studies in this field. At the present time, the cost effects of the release of industrial effluents are minimal, but this may change in near future.

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