



Center for Advanced Wood Processing
University of British Columbia
2424 Main Mall
Vancouver, B.C.
V6T 1Z4

BLEACHING AND FINISHING OF MOUNTAIN PINE BEETLE AFFECTED LODGEPOLE PINE WOOD

By

**Professor Philip D. Evans;
Dr. Mohammed Jahangir Chowdhury**

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*BLEACHING AND FINISHING OF MOUNTAIN PINE BEETLE
AFFECTED LODGEPOLE PINE WOOD*

Bleached MPB Lumber

Untreated MPB Lumber



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EXECUTIVE SUMMARY

Large volumes of blue-stained lumber from trees infected by the mountain pine beetle are now being processed by companies in British Columbia. A preliminary study completed by the Center for Advanced Wood Processing at the University of British Columbia showed that a strong solution of sodium hypochlorite was effective at removing the blue colour from lodgepole pine wood affected by mountain pine beetle and associated fungi.

This study attempted to optimize the bleaching of blue-stained lodgepole pine sapwood using solutions of sodium hypochlorite applied by either soaking the wood in solutions of bleach or spraying the stained wood with bleach. Soaking lumber in a 5% sodium hypochlorite solution at 20°C was effective at removing the blue colour from stained lodgepole pine, and, to a lesser extent, lightening the stained wood. When the sodium hypochlorite was sprayed on to the stained wood, a stronger solution (10.5%) was needed to remove the blue discolouration, however such a treatment was ineffective at lightening the wood.

The utilization of blue-stained wood for painted, non-structural, products is attractive because painting masks the stain. Preliminary research, however, showed that the ability of conventional primers to mask blue stain is lost when the painted wood is exposed outdoors. Paint films applied over sapwood affected by blue-stain appeared to be more susceptible to colonization by mold fungi when the painted wood was weathered. It is not known whether this undesirable property of painted blue-stained lumber is due to the presence of the blue-stain or is simply an inherent characteristic of the sapwood of lodgepole pine. To understand and resolve this issue, an experiment using a range of finishes applied to both stained and unstained sapwood and heartwood boards has commenced. Coated samples are being exposed to the weather in an exterior trial in Vancouver, and monitoring of the exposed boards will be undertaken in the coming fiscal year 2006/07.

2. Bleaching and Finishing of Mountain Pine Beetle-Affected Lodgepole Pine Wood

This report has three components. Each will be described in detail below.

2.1. Optimization of treatment parameters (treatment time, temperature and solution concentration) for bleaching of blue stained wood by soaking lumber in sodium hypochlorite solutions

2.1.1. Introduction

The abundance of beetle infested lodgepole pine in the interior of British Columbia has presented the softwood lumber industry with a problem. The dark coloured hyphae of fungi introduced into the wood by the mountain pine beetle cause the sapwood of infected lodgepole pine to turn a bluish colour. This blue stain, while acceptable for the Japanese Agricultural Service (JAS) grade of structural lumber, is not acceptable to the customers who are used to a clean white wood product from BC mills. Accordingly, many SPF sawmills in British Columbia are experiencing lost revenue because they cannot export blue-stained lumber to Japan that would be acceptable to the customer if the stain was not present.

This study is a continuation of previous experimentation performed at the University of British Columbia's Centre for Advanced Wood Processing. The initial study compared several different bleaching agents for their ability to remove the blue colour from stained lodgepole pine. It was found that a 10% solution of sodium hypochlorite was the most effective bleach of those tested at removing the blue colour from blue-stained sapwood. This study examined the effect of different concentrations of sodium hypochlorite, different temperatures and various soaking times on the presence of blue stain in lodgepole pine affected by mountain pine beetle. Another form of hypochlorite, calcium hypochlorite, was also tested at one concentration.

2.1.2. Materials and Methods

Four separate kiln dried and planed lodgepole pine boards measuring 38.0 x 88.9 x 3658 mm were selected based on the amount of blue stain present in the sapwood. Each board was used as one replication within the experiment. The boards were cut into four 914.4 mm long sections which were each randomly assigned to one of the four temperatures to be tested; 10°C, 20°C, 30°C and 40°C. Each 3' section was then cut into three 305 mm long sections. These were then randomly assigned to one of the three soaking times; 10 minutes, 40 minutes and 120 minutes. These were then further cross-cut into four 76.2 mm long specimens, which were randomly assigned to one of the four treatment types; 0% (water), 5% sodium hypochlorite, 12% sodium hypochlorite and 12% calcium hypochlorite. Plastic containers measuring 390 (length) x 285 (width) x 125 mm (depth) were filled with 3.0 L of the treatment solution and specimens were submerged in the solution so that their upper radial faces were approximately 1 cm below the surface of the liquid. Specimens exposed to treatment temperatures of 10 and 20°C were kept in a refrigerator and conditioning room, respectively. Specimens exposed to temperatures of 30°C and 40°C were placed in ovens. After soaking for the desired length of time, specimens were removed from the treatment solution and rinsed with 100mL of water, and left to air-dry in a conditioning room for 3 days. A Minolta spectrophotometer (CM-2600d) was then used to obtain the L* and b* colour space parameters for each specimen.

The L* parameter indicates lightness (represented on a scale of 0 [black] to 100 [white]), while b* indicates the degree of blueness or yellowness represented on a scale of -60 [blue] to 60 [yellow]. After specimens from the first board were treated with the different bleaches, experimentation commenced on replicates cut from the second board, and so on.

The experiment was designed to examine the effects of three fixed factors (treatment type, temperature and soaking time) on the response variables (the L*

and b* colour parameters). The significance of the three factors on these response variables was determined using a multi-factorial analysis of variance at the 5% significance level. Statistical computation was performed using Genstat. Before the final analysis, diagnostic checks for the normality of the data were performed. Results are presented in graphs and least significant difference bars are used to compare individual means.

2.1.3. Results and Discussion

Table 1 summarizes the significance of the experimental factors, bleach type, temperature and time on the lightness (L*) and blueness (b*) of blue stained lodgepole pine after application of bleaching treatments.

Table 1. Significant effects of and interactions between treatment, temperature and time on L* and b* values of blue stained lodgepole pine after application of bleaching treatments

Response Variable	Experimental Factors						
	Temp.	Time	Treat.	Temp. x Time	Temp. x Treat.	Time x Treat.	Temp. x Time x Treat.
L*	NS	NS	***	NS	NS	NS	NS
b*	*	NS	***	NS	**	NS	NS

* = p < 0.05; ** = p < 0.01; *** = p < 0.001; NS = not significant (p > 0.05)

Treatment type had a significant (p<0.001) effect on the lightness and blue colour of blue-stained lodgepole pine. Treatment temperature also had a significant (p<0.05) on the blue colour of the stained pine and there was a significant (p<0.01) interaction of treatment and temperature on b*. Figure 1 shows the effect of the different treatment types on the lightness of blue-stained lodgepole pine.

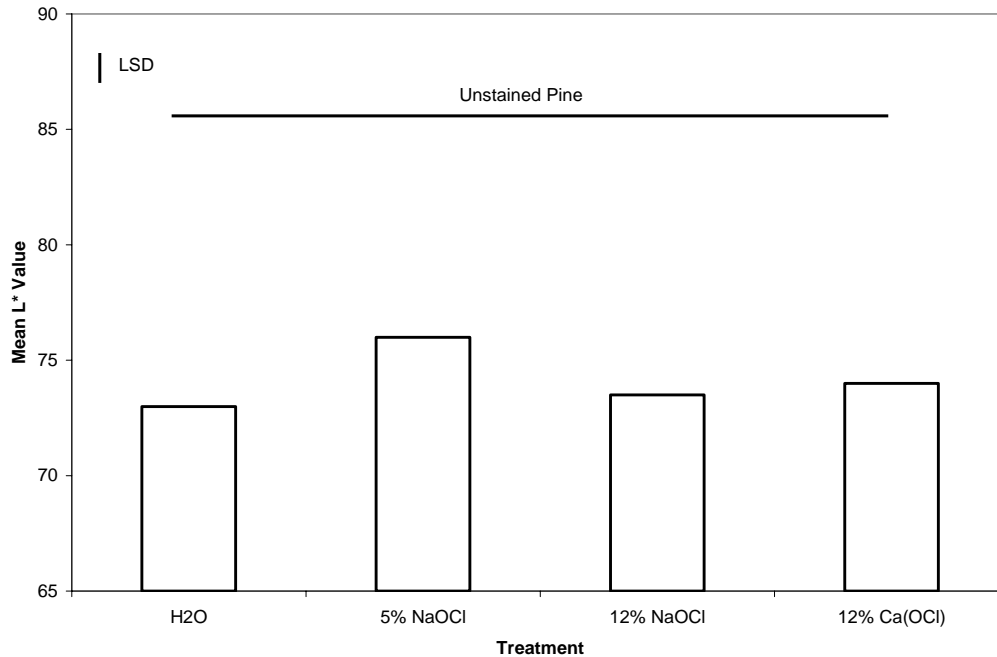


Figure 1. Effect of treatment type on the lightness (L^*) of blue stained lodgepole pine

It can be seen from Figure 1 that specimens submerged in the 5% sodium hypochlorite solution were significantly lighter after treatment than those submerged in either the 12% sodium hypochlorite or 12% calcium hypochlorite solutions. The straight line at the top of Figure 1 represents the mean L^* value for unstained pine samples. None of the treatments were able to return the blue-stained specimens to their original brightness, but specimens treated with 5% sodium hypochlorite solution were significantly lighter than the other specimens treated with the stronger solutions of bleach or water. The finding that the 5% solution of sodium hypochlorite was more effective at lightening the stained wood than the 12% solution was unexpected. It is possible that the lower viscosity of the 5% solution allowed for deeper penetration of the bleaching agent into the sapwood of the blue-stained pine, but further experimentation would be needed to confirm this.

Figure 2. shows the effects of treatment type and temperatures on the b^* values (blue colour) of stained sapwood.

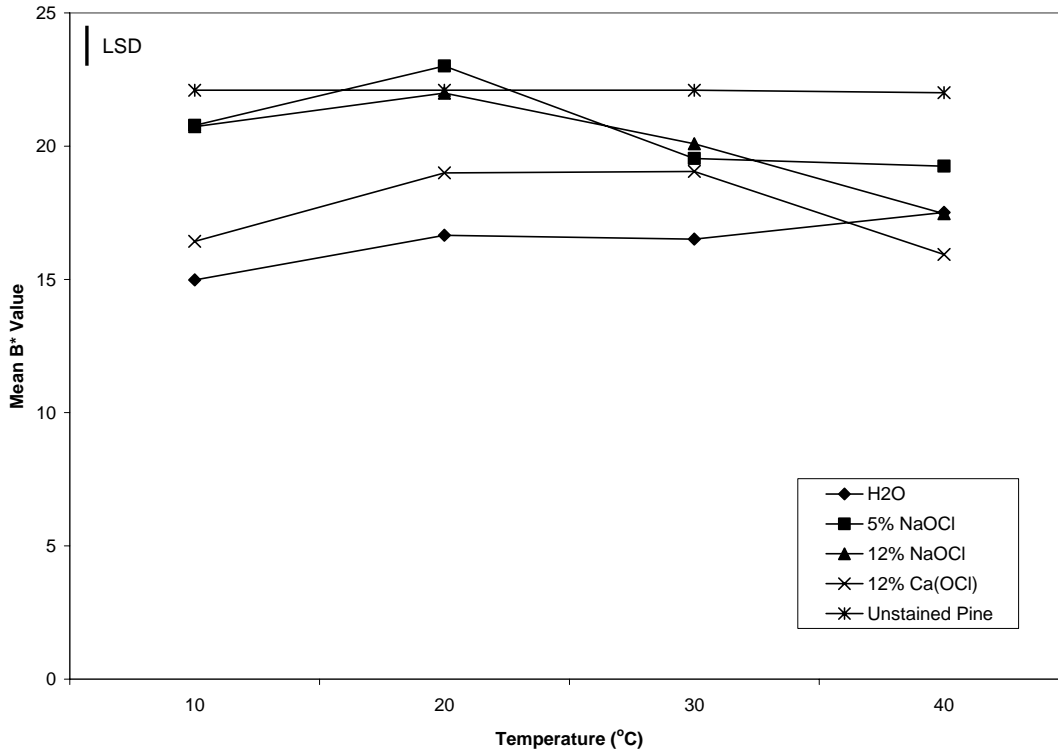


Figure 2. Effect of treatment type and temperature on b^*

The 5% sodium hypochlorite solution maintained at 20°C was the most effective treatment at removing the blue discolouration from blue-stained sapwood. All of the solutions, except for water (control), had a similar effect on the blue colour of stained pine when they were maintained at 30°C. Treatment of stained wood with 5% and 12% solutions of sodium hypochlorite at 10°C and 20°C resulted in mean b^* values that were similar to that of unstained pine. Specimens treated with a 5% solution of sodium hypochlorite at 20°C were less blue than unstained wood. All of the bleaching treatments performed relatively poorly at 40°C. This is possibly due to the fact that hypochlorite solutions break down to form chlorates when exposed to temperatures above 30°C (Pioneer Chemicals 2004). The stability of hypochlorite solutions is also influenced by the presence of anionic and cationic compounds (Bommaraju 1995).

2.1.4. Conclusions

Bleaching treatment type and temperature had significant effects on the blueness and lightness of blue-stained lodgepole pine submerged in an excess of bleach. The most effective treatment at removing the discolouration from blue-stained lodgepole pine sapwood was a 5% sodium hypochlorite solution maintained at a temperature at 20°C. The mean b^* value of blue-stained sapwood after soaking in this solution was similar to that of unstained pine. This treatment was also the most effective at lightening the wood, but the L^* value obtained after treatment was lower than that of unstained pine. Overall it can be concluded that soaking lumber in a 5% sodium hypochlorite solution at 20°C is quite effective at removing the blue colour of stained lodgepole pine and, to a lesser extent, lightening the wood.

2.1.5. References

Pioneer Chemicals. 2004 (July 23). Stability of Hypochlorite Solutions. <<http://www.piona.com/tech/data/naocl/STABILITY.pdf>>.

Bommaraju, T. V. 1995. Sodium Hypochlorite: its Application and Stability in Bleaching. Water Quality Research Journal of Canada, 30(2): 339-361.

2.2. Optimization of treatment parameters for the bleaching of blue-stained lumber using sodium hypochlorite solution applied by spray

2.2.1. Introduction

Lodgepole pine (*Pinus contorta* var. *latifolia* S. Wats) grows abundantly in the northern and central regions of British Columbia, and sustains a large sawmilling industry supplying structural lumber for domestic and export markets and, to a lesser extent, wood for appearance-grade products such as furniture. Increasing volumes of this lodgepole pine lumber are being cut from trees infected by the mountain pine beetle and associated pathogenic fungi that cause the sapwood of newly infected trees to become blue-grey in colour (Langor 2003). Large volumes, in excess of 18 million cubic metres, of lodgepole pine are affected by mountain pine beetle, and blue-stained wood from this resource will form a significant proportion of lumber produced in British Columbia for the foreseeable future (COFI 2004). Clearly, in appearance-grade applications such as furniture, the presence of stained wood is undesirable, but in certain grades of structural lumber it may also be considered undesirable. For example, the Japanese market place for spruce-pine-fir lumber, which includes lodgepole pine, does not readily accept the presence of any stain on structural lumber.

The blue colouration of blue-stained wood is produced by melanin in the hyphae of the fungi that colonize wood (Zink and Fengel 1990). Various chemicals, including alkaline solutions of hydrogen peroxide, can bleach melanin and there has been interest in using bleaching agents to remove the blue colouration from blue-stained wood (Lee et al. 1995; Oh et al. 1997). The patent literature also contains a number of references to solutions of bleaching agents said to be effective at removing fungal stains from wood (Deniskin et al. 2000; Hayashi et al. 1974; Okabe 1981; Suzuki and Ihara 1986).

Previous research by the proponents (funded by the Canadian Forestry Service under the Mountain Pine Beetle Initiative) screened a range of bleaching

chemicals to determine which one was most effective at removing the blue colour from blue-stained lodgepole pine. The most effective chemical at removing the blue stain from lodgepole pine was found to be sodium hypochlorite, applied at room temperature as an aqueous solution at a concentration of 10%. Sodium hypochlorite is an inexpensive and readily available chemical that is widely used industrially for waste water treatment and as a component of household bleaches. It has the potential to be used by industry to remove blue stain from lumber, but a suitable commercial industrial treatment process needs to be developed. A pre-requisite to the development of such a treatment process is the knowledge of the effect of treatment parameters such as solution concentration, treatment time and temperature on the ability of sodium hypochlorite to remove blue stain from lumber. Further knowledge in these areas could allow the treatment to be optimized by accelerating treatment time and reducing the concentration of bleaching chemical. In the first part of this research the effect of different concentrations of sodium hypochlorite, different treatment temperatures and different soaking times on the colour of blue-stained wood soaked in solutions of sodium hypochlorite was examined. The research in Part II of this report focuses on application of bleaching agents by spraying as this may be a more practical commercial way of applying the bleaching agents than soaking. Experimentation was performed to examine the effect of different concentrations of sodium hypochlorite and different treatment temperatures on the colour of blue-stained wood.

2.2.2. Materials and Methods

Five separate kiln-dried and planed lodgepole pine boards measuring 38.0 x 88.9 x 3658 mm were selected based on the amount of blue stain present in the sapwood. Each board was used as one replication within the experiment. Each board was cross-cut into five sections. These five sections were randomly assigned to one of the five concentrations of sodium hypochlorite used. These concentrations were 0% (only water), 5%, 7%, 9% and 10.5% sodium

hypochlorite. Four 152.4 mm long specimens were then cut from each section. These four specimens were randomly assigned to one of the four temperatures (20°C, 25°C, 30°C and 35°C). The bleach solutions were sprayed on to the surfaces of the specimens using a conventional spray gun. The rate of application of the bleaching agent was approximately 0.012 mL/cm². The bleach solutions and spraying equipment were pre-heated to the required temperatures before spraying. Upon completion of the treatments, the specimens were air-dried for 24 hours and then rinsed with running water. The specimens were then air-dried at 20°C for 48 hours. A Minolta spectrophotometer (CM-2600d) was used to measure the L* and b* colour space parameters at four different points on each specimen.

The experiment was designed to examine the effects of two fixed factors (bleach concentrations and treatment temperatures of the bleach solutions) on the response variables (L* and b* values). The significance of the two factors on these response variables was determined using a multi-factorial analysis of variance at the 5% significance level. Statistical computation was performed using Genstat. Before the final analysis, diagnostic checks for the normality of the data were performed.

2.2.3. Results and Discussion

Table 2 summarizes the significance of the experimental factors on b* (blue colour). There was no significant effect of the experimental factors on L*.

Table 2 Significant effects of and interactions between two fixed factors on b* values

Response variable	Experimental Factors		
	Concentration	Temperature	Concentration x Temperature
b*	***	NS	*

*** = p < 0.001; * = p < 0.05; NS = not significant (p > 0.05)

The effect of treatment concentration on the blue colour of stained sapwood was highly significant ($p < 0.001$). There was no significant effect of temperature on b^* , but there was a significant ($p < 0.05$) interactive effect of concentration and temperature on b^* .

Figure 3 shows the effect of effects of solution concentration and temperature on the b^* values of blue-stained specimens sprayed with sodium hypochlorite. This interaction occurred because there was no difference in the ability of the strongest bleach solutions (9 and 10.5%) to remove the discolouration from blue-stained wood when they were sprayed on to wood at a temperature of 20°C whereas at higher temperatures (25, 30 and 35°C) the 10.5% solution was more effective than the 9% solution.

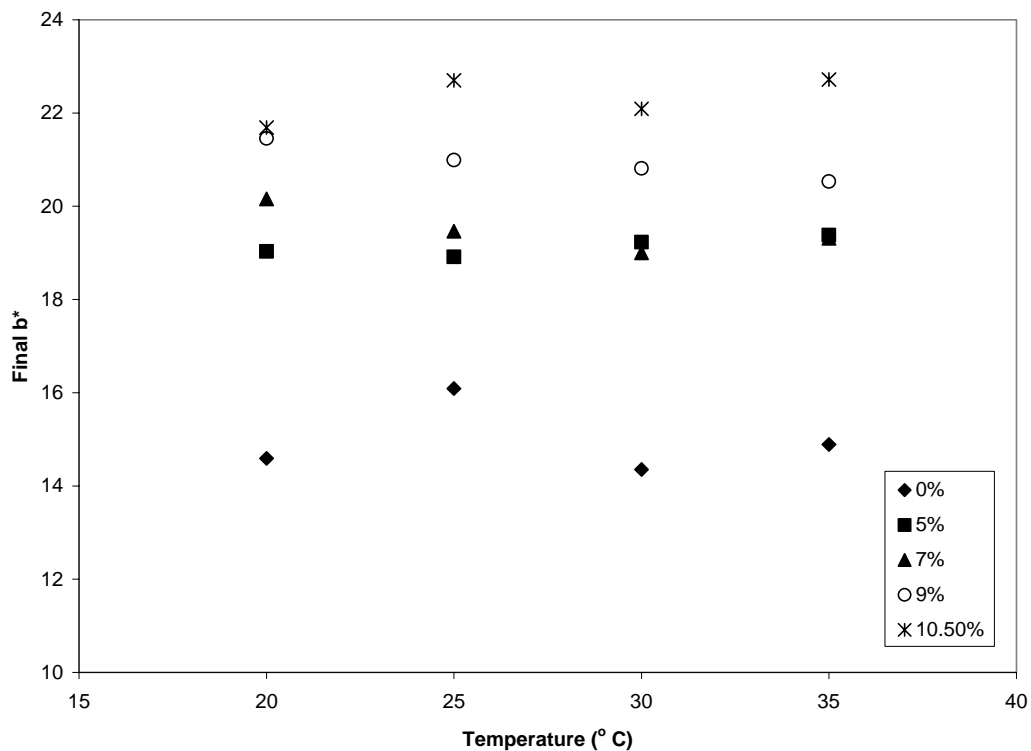


Figure 3. The effect of solution concentration and temperature on the blue colour (b^*) of blue-stained lodgepole pine specimens sprayed with sodium hypochlorite

In general there was little if any benefit of increasing the temperature of the sodium hypochlorite solution above 25°C on reduction of blue stain. The 10.5% sodium hypochlorite solution was the only treatment that completely removed the blue colour from the blue-stained wood, but solutions applied at concentrations of 9%, 7%, and 5% also had a significant ($p < 0.05$) effect at reducing the blue colour of stained lodgepole pine. As mentioned above, none of the treatments were effective at lightening the wood even though they removed the blue stain. This occurred because the bleached wood became slightly green after treatment with sodium hypochlorite.

2.2.4. Conclusions

Concentrated solutions of sodium hypochlorite sprayed on to blue-stained lodgepole pine sapwood at 25°C are effective at removing the blue discolouration from sapwood, and no additional benefit on reduction of discolouration is obtained by increasing treatment temperature. Blue-stain removed wood has a mild green colour after treatment and hence the brightness of the wood is not increased by the sodium hypochlorite treatment to the same level as natural non blue-stained wood.

2.2.5. References

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2.3 Utilization of Mountain Pine Beetle Affected-Wood for Painted Products

2.3.1 Introduction

The utilization of mountain pine beetle-affected lodgepole pine for painted, non-structural wood products (cladding and joinery) is attractive because painting masks the blue stain, and loss of mechanical properties associated with fungal attack is less serious for products that are not used in load-bearing situations. A previous project funded by CFS and undertaken in collaboration with CANFOR, however, found that a range of alkyd and acrylic-latex primers and clear coats on blue stained lumber did not mask the blue-stain when the finished wood was exposed to the weather for a period of 3 months.

The discoloration appeared to be due to organisms colonizing the paint film rather than the blue stain fungus growing through the film. This problem is very serious because it detracts from the appearance of the painted product, will increase maintenance costs and may reduce the longevity of the coating. It is not known whether this undesirable property of painted blue-stained lumber is due to the presence of the blue-stain or is simply an inherent characteristic of the sapwood of lodgepole pine. To understand and resolve this issue, an experiment using a range of finishes applied to both stained and unstained sapwood and heartwood boards was developed. Coated samples are being exposed to the weather in an exterior weathering trial in Vancouver, BC. Monitoring of the exposed boards for gloss, colour, microbial colonization, weight (MC), dimensional change etc. will be undertaken in the coming fiscal year 2006/07. If it is shown that painted blue-stained sapwood is more susceptible to colonization by mold fungi, subsequent research will develop finishes or pre-treatments to prevent colonization of paint films on blue-stained sapwood by mold fungi.

2.3.2. Materials and methods

Four lodgepole pine logs free of blue-stain and four logs containing blue stain were obtained from Alex Fraser Research Forest in Williams Lake, British Columbia. The logs were debarked and sawn 'through-and-through' using a LT-15 Wood Mizer sawmill into two inch boards. Boards were kiln dried over a period of 14 days to a final moisture content of 13%. Two boards from each log were converted into cladding samples measuring 101.6 x 50.5 x 2133.6 mm. All four sides of the boards were planned using a Martin T44 jointer and a Martin T54 thickness planner. All longitudinal edges were rounded to a 5 mm radius using a Martin T26 shaper. The boards were cross-cut into samples, each 6" in length using an Omega radial arm saw. Seven (7) samples from each board were randomly assigned to 7 different wood finishing systems (Table 1) and their end grain sealed using an epoxy-based sealer. Samples were conditioned at $20 \pm 1^{\circ}\text{C}$ and $65 \pm 5\%$ relative humidity for 1 month. Seven different wood finishing systems (opaque, white, acrylic and alkyd finishes) were applied (primer plus two topcoats) to the different samples in accord with manufacturers instructions. The description of the wood finishing systems is given below (Table 3).

Table 3. Coating systems applied to blue stained and unstained lodgepole pine samples

System No.	Primer	Top coat	Drying times (h)*
1	CIL smart, 100% acrylic, white, water-based	Dulux exterior latex, 100% acrylic, white, gloss, water based	16, Primer (12) 6, Topcoat (4)
2	CIL smart, 100% acrylic, white, water-based	Dulux exterior latex, 100% acrylic, pure white 1500, satin, water-based	16, Primer (12) 6, Topcoat (4)
3	Dulux # 999 primer, alkyd, oil-based	Dulux, exterior, semi gloss, alkyd, oil-based	16, Primer (12) 12, Topcoat (12)
4	Behr # 436, 100% acrylic, white, water-based	Behr, exterior satin enamel, 100% acrylic latex, white	16, Primer (12) 6, Topcoat (4)
5	Behr # 436, 100% acrylic, white, water-based	Behr, exterior flat, 100% acrylic latex, pure white	16, Primer (12) 6, Topcoat (4)
6	Kilz oil-based sealer and stain blocking primer	Dulux exterior latex, satin, 100% acrylic, pure white 1500, water-based	16, Primer (12) 6, Topcoat (4)
7	Control (uncoated)	Control (uncoated)	Control (uncoated)

*Recommended drying times in parentheses

Coated samples were conditioned for 1 month and the colour of the finishes on coated samples was measured using a spectrophotometer (Minolta CM-2600d). Initial gloss, weight and dimension of the test samples were also measured. Coated samples were exposed outdoors in Vancouver on a vertical test fence, facing south (Figure 4).

Figure 4. One of four test fences used to expose painted blue-stained samples to the weather



2.3.3. Next steps

Coated and uncoated samples will be brought back to the laboratory each quarter and will be wiped clean with a lint-free cloth, conditioned for 1 week and the colour, gloss, microbial colonization, weight (moisture content) and dimensional change will be re-measured.