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Short Note

Preliminary Evaluation of Silicon Tetrachloride As a Wood Preservative

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Preliminary evaluation of silicon tetrachloride as a wood preservative

Summary

Preliminary decay tests indicated that $SiCl_4$ treatment may be useful as a method of wood preservation. $SiCl_4$ readily penetrated blocks of red pine (*Pinus resinosa*) sapwood and both sapwood and heartwood of Douglas fir (*Pseudotsuga menziesii*). The $SiCl_4$ treatment significantly reduced decay caused by both whiterot and brownrot fungi.

Schlüsselwörter
(Sachgebiete)
Holzbefall
Siliciumtetrachlorid
Weißfäule
Braunfäule
Splintholz
Kernholz
Redwood (Rotkiefer)
Douglasie

Vorläufige Bewertung von Siliciumtetrachlorid als Holzschutzmittel

Zusammenfassung

Schutzmittelvorprüfungen ergaben, daß eine Siliciumtetrachlorid-Behandlung als Holzschutzmethode brauchbar sein könnte. Siliciumtetrachlorid dringt leicht in Splintholz von Redwood sowie in Splint- und Kernholz von Douglasie ein. Durch die Behandlung vermindert sich der Befall durch Weiß- und Braunfäulepilze beträchtlich.

1. Introduction

Dissatisfaction with currently used wood preservative materials is prompting a continuing search for better materials and methods for inhibiting wood decay. Preservatives in use at present suffer from undesirably short periods of effectiveness and from either real or suspected detrimental environmental impacts. In some cases, incomplete penetration of the preservative into the wood is also a problem.

An alternative is needed that is environmentally safe, effective for long periods of time, and relatively inexpensive. In this paper we report initial experimental results which indicate that silicon tetrachloride should be carefully examined as such an alternative. A consideration of its chemical properties led to the expectation that silicon tetrachloride may serve as a wood preservative.

Silicon tetrachloride is a clear, colorless, mobile liquid, with normal boiling point 57°C. The Si-Cl-bonds are very reactive towards hydroxyl groups in water and alcohols; for example

$$SiCl_4 + 3H_2O \longrightarrow H_2SiO_3 + 4HCl \quad (1)$$

This reactivity suggests that if $SiCl_4$ is introduced into wood, it can be expected to react with any water present and with hydroxyl groups of cellulose. Subsequent oven drying will drive off the HCl formed and will decompose any silicic acid.

$$H_2SiO_3 \longrightarrow H_2O + SiO_2 \quad (2)$$

The result may be wood containing (1) silica gel that will act as a water trap, effectively keeping the wood "biologically dry", and (2) cellulose chains cross-linked by -O-Si-O- groups. Such cross-linked cellulose may be unusable as food by microorganisms.

To test this hypothesis, samples of red pine sapwood, Douglas-fir sapwood and Douglas-fir heartwood, were treated with $SiCl_4$, oven dried, and exposed, along with untreated control samples, to one whiterot fungus and several brownrot fungi.

2. Material and Methods

Test samples were blocks 2 × 2 × 1 cm of red pine (*Pinus resinosa* Ait.) sapwood, Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) sapwood, and Douglas-fir heartwood. After drying 24 hrs at 104°C the blocks were treated by immersing them for 60 seconds in $SiCl_4$ at room temperature. Upon immersion, initially vigorous bubbling, which gradually subsided within 60 seconds, was observed. Treated blocks and untreated controls were brought to constant weight at 104°C, cooled in a desiccator and weighed (initial oven-dry weight).

The blocks were returned to the oven at 104°C in sterile petri plates for 24 hrs, then removed, cooled, and transferred asceptically to decay chambers. French square 8 oz bottles in

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Table 1

Mean weight loss due to decay caused by six fungi in $SiCl_4$ treated red pine

Decay fungi	Mean weight loss (%)[a] 8 Week		16 Week	
	Control	Treated	Control	Treated
Control	0	4	0	3
Polyporus versicolor	29	6	43	8
Lenzites saepiaria	30	5	47	7
Lentinus lepideus	24	6	51	7
Poria monticola	18	6	36	8
Poria vaillantii	4	5	14	6
Poria carbonica	1	6	2	6

[a]) Mean of 4 obs. 8 wk, LSD ($P < 0.05$) = 3.0; 16 wk, LSD ($P < 0.05$) = 4.2

the horizontal position containing 25 ml of media served as decay chambers. Media consisted of malt-yeast agar (g/l: malt extract 10, yeast extract 2, agar 20). The chambers were incubated one week at 23°C with the specified fungi (or none) before the blocks were added. During the tests the chambers and blocks were kept in the dark at 23°C.

Harvests were made at 8 and 16 weeks: 4 or 5 blocks were removed, surface mycelium carefully removed, and a "fresh weight" taken. The blocks were placed in the oven at 104°C until constant "final oven-dry weight" was obtained. Moisture content was calculated by equation (3)

$$\text{Percent } H_2O = \frac{Fw - Fd}{Fd} \times 100 \quad (3)$$

and weight loss by equation (4)

$$\text{Percent loss} = \frac{Id - Fd}{Id} \times 100 \quad (4)$$

where Fw = fresh weight at harvest
Id = initial oven dry weight at 104°C
Fd = final oven dry weight at 104°C

Treated red pine sapwood samples were exposed to six fungi: *Polyporus versicolor* L. ex Fr. (white-rotter), *Lenzites saepiaria* Fr., *Lentinus lepideus* Fr., *Poria monticola* Murr., *Poria vaillantii* (DC ex Fr.) Cke., and *Poria carbonica* Overh. (all brown-rotters). The isolates of brownrot fungi were all taken from Douglas-fir poles in sevice, and were kindly provided by Dr. Robert Zabel, (State University of New York, Syracuse). Douglas-fir sapwood and heartwood were exposed to four decay fungi: the white-rotter and the first three brown-rotters listed above.

Table 2

Mean weight loss due to decay caused by four fungi in $SiCl_4$ treated sapwood and heartwood of Douglas fir

Tissue type and Decay fungus	Mean weight loss (%)[a] 8 Week		16 Week	
	Control	Treated	Control	Treated
Sapwood				
Control	0	1	0	1
Polyporus versicolor	9	3	25	3
Poria monticola	11	3	27	4
Lenzites saepiaria	8	2	18	3
Lentinus lepideus	5	2	26	3
Heartwood				
Control	0	1	0	0
Polyporus versicolor	5	2	13	2
Poria monticola	8	2	25	4
Lenzites saepiaria	4	2	14	2
Lentinus lepideus	2	2	12	2

[a]) Mean of 5 obs. 8 wk, LSD ($P < 0.05$) = 2.4; 16 wk, LSD ($P < 0.05$) = 3.0

3. Results

After periods of up to 16 weeks, the weight loss and water content of treated samples were compared with that of controls. The results uniformly show that treated samples suffer significantly less weight loss than do the untreated controls (Tables 1 and 2). Weight loss in treated samples is generally below levels that indicate decay, although the fungi did grow on sample blocks and cause small losses in weight.

Table 3

Mean water content of incubated wood samples at time of harvest

Tissue type and Incubation time (Wk)		Mean water content (% dry weight)[a] None	*Polyporus versicolor*	*Lenzites saepiaria*	*Lentinus lepideus*	*Poria monticola*	*Poria vaillantii*	*Poria carbonica*
Red pine								
Sapwood	8	150	310	260	210	270	220	190
	16	150	320	330	330	330	250	200
Treated sapwood	8	150	210	220	210	220	210	220
	16	150	230	220	220	220	220	220
Douglas-fir								
Sapwood	8	60	110	140	100	150		
	16	70	160	120	120	190		
Treated sapwood	8	100	120	120	120	120		
	16	110	130	130	120	130		
Heartwood	8	40	110	110	80	150		
	16	40	150	150	100	190		
Treated heartwood	8	100	120	130	140	140		
	16	90	130	140	140	90		

[a]) Mean of 4 obs. in pine and 5 obs. in Douglas-fir

There is also a small, but consistent weight loss of 3—4 % in pine and 1 % in Douglas-fir, which cannot be attributed to action of decay fungi.

Sample blocks appeared to absorb equal amounts of water when incubated with fungi (Table 3). Water absorbed by inoculated blocks treated with $SiCl_4$ was generally uniform regardless of length of incubation, or type of inoculum; whereas untreated blocks varied with amount of decay — more decay, higher water content.

4. Discussion

It is clear from the results shown, that treatment of blocks of red pine sapwood, Douglas-fir sapwood, and Douglas-fir heartwood with silicon tetrachloride, significantly reduced the decay caused by both whiterot and brownrot fungi. The successful treatment of heartwood is particularly noteworthy because contemporary treatments are not effective.

We observed a (presently unexplained) weight loss of up to 4 % in $SiCl_4$ treated, noninoculated samples. Similar nontreated, noninoculated samples show zero weight loss or even a slight gain in weight. If small amounts of HCl (a volatile product of the reaction of $SiCl_4$ and hydroxyl groups) are somehow trapped in the wood, but escape slowly over a period of several weeks, a small weight loss would occur between the initial oven-dry weight and the 8 and 16 week harvests. Alternatively, such a weight loss could result from a slow decomposition of silicic acid, by eqn (2). Again, small amounts of H_2SiO_3 that are present at the time of initial oven dry weighing and that slowly decompose over several weeks would appear as a small weight loss. This phenomenon will be studied in future experiments.

A claim that $SiCl_4$ is indeed an acceptable alternative preservative material would be premature at this time. Much more work is needed. Considerably more testing is required with larger samples under more severe conditions. Considerably more development of treatment procedures is needed. And a better understanding of the fundamental chemistry involved is essential. But the desirability of such work certainly appears to be justified.

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