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Mold Control for Treated Lumber in Block-Stack Storage Conditions

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ABSTRACT

The mold development and control for freshly treated and block-stacked wood have been evaluated using a green house mold testing method. The results for the mold resistance of several commonly used water boron preservative treatment systems, such as ACQ, Copper Azole, and borates with and without inclusion of mold inhibitors are presented. The data suggest that the different preservative treatment systems have their own very different mold resistance characteristics. The addition of mold inhibitor or in some cases combination of mold inhibitors or additives can provide effective control of mold development. The results also suggest that the green house mold test method reported here can simulate the worst case scenario confronted by treated wood in block-stack situations during storage, retailing and installation.

Keywords: mold test, green house method, mold inhibitor, ACQ, Copper Azole, CA-C, Borate, DOT, Quat, water repellent, tebuconazole, propiconazole, isothiazolinone

INTRODUCTION

Traditionally, the treated lumber industry is pressure treating wood with waterborne chemicals to protect against decay and insect attack. The most common inorganic water based preservatives used in the market are CCA, copper-based preservatives (soluble copper and particulate copper-based in the eastern US), borate and quat based or combination products. Recently, new products with organic chemical based preservatives (Tebuconazole, DCOIT, Propiconazole, IPBC and others) usually in combination the use of water repellents and other stabilizers have been commercialized in the US and elsewhere for above ground applications. In addition to the biocide- based treatments mentioned, chemically and thermally modified wood, as well as wood plastic composite lumber (WPC) are now also marketed for certain construction applications.

In general, these lumber and composite products are produced and stored in large block-stacked packs. Often, it is common practice for these materials to be stored, shipped, and distributed before while still wet as a result of the treatment process. In these conditions, although the lumber is not generally subject to attack by wood destroying organisms such as fungi and insects, the materials are subject to surface mold development which can be a significant problem during storage, retailing and installation.

The assessment of mold, and its control, on treated products in block-stack storage conditions is critical in the determination of mold development potential in commercial applications. Currently, the standardized mold testing methods used are ASTM D3273 (1) and AWPA E24 (2). Other modified testing procedures (4, 5) are also reported. The AWPA and ASTM laboratory methods are designed for the mold evaluation testing against specified pure mold culture. The test samples (wood or composites) are conditioned to the same moisture level and the designated mold culture suspension to be used. The test chamber requires temperature, air flow and moisture content control to accelerate mold growth. In these standardized tests the specimen's size is small and the samples are spaced apart from each other so that the mold development can be assessed by individual pieces of samples. Though these methods are instructive in evaluating the relative performance of end-products in comparison with known controls, they do not simulate the conditions confronted by treated wood in block-stack storage conditions.

In this paper, the mold control of the treated lumber in block-stack storage is evaluated in a green house setting to simulate the worst case scenario of natural environment in terms of treated lumber and mold species involved but with the accelerated conditions such as elevated temperature and humidity. We have used this method with considerable success for the past 10 years. The test results of using this methodology with several water borne preservative systems with and without mold inhibitors are reported.

EXPERIMENTAL METHODS

Treatment Samples

Southern pine (nominal 2x4 - 8' #2) lumber was cut into 300 mm treatment specimens. Boards were selected for samples that were visually free of sapstain and mold infection. The samples were randomized into treatments groups of designated treatments and labeled with sample and treatment number.

Treatments

Various preservative treatment systems were used in many different tests by our research group over the years. In this paper, three sets of test results are provided to illustrate the method and the evaluation process. For all of the tests, the materials were pressure treated using common industry treatment practices for water-borne preservatives. The three groups of treatments included in this report were as follows:

1) ACQ type C (with BAC as co-biocide) with and without water repellent (WR) targeting an actives retention of 4 kg/m^3. Two types of mold inhibitors (K1 and K2, both are isothiazolinone based) were used in combination with the ACQ treatments. The several levels of mold inhibitors were used in the test to evaluate the effectiveness.

2) Soluble and particulate copper azole type C (CA-C) treated wood at above ground retention of 1.0 kg/m^3. Two types of mold inhibitors (K1 and K2) were used in combination with the both type of CA-C treatments. Several levels of mold inhibitors were used in the test to evaluate the effectiveness.

3) Disodium octaborate tetrahydrate (DOT) treatment at a solution concentration of 1.2% with and without mold inhibitor (K1) and various quaternary ammonium compounds (Quats as: Q1, Q2 and Q3) as additives at various solution concentrations.

Mold Testing

After treatment, the wood samples were block-stacked together for a very short period of air drying (24 hr) before being installed into test. The samples were placed on the top of a black plastic covered wood runner box. The plastic covered wood runner box was used for two purposes:
1) To support the samples above the bottom in a fungus cellar bin or in the floor of the greenhouse.
2) To store the water in the box to maintain the wetness of the testing sample.

Previously naturally moldy wood samples had been washed to generate water with mold spore and mycelia. The wood box with plastic liner was then filled with this mold "infected" water. In some cases, moldy wood was put in the water bath (see photos below for both cases). For the above three tests, the samples were block-stacked in treatment groups three wide by five high or four wide by four high on the runners for each treatment (total 15 or 16 of 50x100x300mm board sections) with the treatment groups separated by approximately 40mm. The stacks of samples were covered with black polyethylene plastic to retain moisture. The green house has been maintained at a condition about 27^{o}C and variable elevated humidity. Photos of the representative test assemblies are presented below.




Mold Resistance Evaluation

The samples were inspected periodically and rated for mold growth. The rating scale was based on the mold surface coverage of the samples (see table below). After each evaluation, the water in the troughs was replenished to maintain optimal humidity for good mold growth conditions within the plastic covered environment. A representative photo of the mold growth and control is shown below for the illustration.

Surface Coverage	Mold Rating
0	0
<5%	0.5
5-10%	1
10-25%	2
25-50%	3
>50%	4

RESULTS AND DISCUSSION

The test results from the ACQ type C, CA-C, and DOT treatments are presented in the Table 1, 2 and 3 respectively.

Table 1. Mold resistance of ACQ type C treated wood

		Active	Average Ratings of 15 samples for each treatment				
Treatment	**Mold Inhibitor**	**ppm**	**54days**	**76days**	**98days**	**124 days**	**150days**
ACQ type C	None	0	0.30	0.63	0.97	1.93	2.60
	K1	15	0.00	0.00	0.00	0.20	0.37
	K1	30	0.00	0.00	0.00	0.07	0.07
	K1	45	0.00	0.00	0.00	0.00	0.00
	K2	100	0.00	0.00	0.20	0.43	0.73
	K2	200	0.00	0.00	0.03	0.17	0.27
ACQ type C+WR	None	0	0.60	3.13	3.73	4.00	4.00
	K1	15	0.00	0.13	0.37	1.23	2.20
	K1	30	0.00	0.00	0.10	0.93	1.30
	K1	45	0.00	0.00	0.07	0.33	0.67

Table 2. Mold resistance of CA-C treated wood

		Active	Average Ratings of 15 samples for each treatment		
Treatment	**Mold Inhibitor**	**ppm**	**49days**	**114days**	**164days**
Soluble CA-C	None	0	2.38	4.00	4.00
	K1	45	0.00	0.65	1.65
	K1	100	0.00	0.00	0.00
	K1	200	0.00	0.00	0.00
	K1/K2	45/200	0.00	0.08	0.13
Particulate CA-C	None	0	3.80	4.00	4.00
	K1	45	0.00	0.63	4.00
	K1	100	0.00	0.25	2.70
	K1	200	0.00	0.05	0.35
	K1/K2	45/200	0.00	0.13	1.43

Table 3. Mold resistance of Borate (DOT) treated wood

Borate (DOT)	Quat %			K1	Average Ratings of 15 samples for each treatment			
1.2% Treatments	**Q1**	**Q2**	**Q3**	**ppm**	**19 days**	**40 days**	**84 days**	**128 days**
1	0.2%				0.42	3.33	4.00	4.00
2	0.4%				0.00	1.38	3.92	4.00
3		0.2%			0.04	1.08	3.83	4.00
4		0.4%			0.04	0.50	2.17	3.42
5			0.2%		0.18	1.58	3.75	4.00
6			0.4%		0.00	0.21	2.92	4.00
7	0.1%		0.1%		0.00	0.71	3.75	4.00
8	0.2%		0.2%		0.25	1.83	3.83	4.00
9		0.1%	0.1%		0.00	2.33	3.92	4.00
10		0.2%	0.2%		0.42	2.08	3.83	4.00
11	0.1%		0.1%	45	0.00	0.00	0.00	0.13
12		0.1%	0.1%	45	0.00	0.00	0.00	0.00
13	0.2%			45	0.00	0.00	0.00	0.00
14		0.2%		45	0.00	0.00	0.08	0.25
15				45	0.00	0.00	0.21	2.29
16					4.00	4.00	4.00	4.00

The data show that wet and block-stacked ACQ type C treated wood with no additional mold inhibitors under the very severe test conditions could resist significant mold growth for about 2 months. However, continuing with moist/warm/humid conditions could allow mold development to become a significant negative issue. The addition of mold inhibitor K1 at 45ppm active concentration allowed for total control of mold growth for 5 months during the test period. Mold inhibitor K2 was not as effective as K1 even at a use level of 200ppm but did provide good control for more than 3 months. The data for ACQ type C treated wood with water repellent (WR) suggest that inclusion of WR in the preservative treatment could induce faster mold growth initially than is seen with non-water repellent formulations of the same preservative. It is long recognized that WR treated wood after drying is very water resistant for a long period of time during service and prevents moisture intrusion into the wood. However, the speed of initial drying of WR treated wood after treatment is usually slower than for non-WR treated wood. This longer water retention after treatment presumably is the key factor in the enhanced mold development seen on WR treated wood relative to that of comparably treated non-WR wood. The data demonstrated that with 45ppm K1, the mold growth could be controlled for ACQ/WR treated wood under the very severe conditions used in this test.

The mold growth data from copper azole type C (CA-C) with both soluble (amine copper azole) and particulate (micronized) formulations are interesting. The soluble copper CA-C treated wood without mold inhibitor had mold growth much faster than that seen with ACQ-type C with more than 20% surface mold coverage around 50 days. The inclusion of quat (in the case of BAC in ACQ type C) which has some mold resistance may contribute to this better performance of ACQ against mold than with the soluble CA-C. The azoles in CA-C are tebuconazole and propiconazole. Tebuconazole is a good fungicide (7) but provides little effectiveness against mold, while propiconazole is known as providing more protection against some molds but perhaps the level was too low at the 1 kg/m^3 of CA-C above ground retention used to be effective. Addition of mold inhibitor K1 at 45ppm provided short term control for mold growth. Using 100ppm of K1 or a combination of K1/K2 at 45ppm/200ppm provided good control of mold growth for the soluble CA-C.

It was somewhat surprising to see that the particulate CA-C performed poorer than soluble CA-C in our tests, since one theory that has been postulated is that the ethanolamine in amine copper systems provides a nitrogen source that enhances mold development in wood in storage. More likely, is that the molds usually predominating on amine copper systems tend to be white molds which are more apparent than the non-white molds seen on other preservative treated wood such as CCA. Perhaps formulating agents in the particulate CA-C formulation may be contributing to the mold growth but that is not determinate in this study. For the particulate CA-C tested in this study, both K1 and K1/K2 combination mold inhibitors could provide control but were less effective than in the case of soluble CA-C at the same mold inhibitor concentrations.

The mold control experiment for borate (DOT) treated wood showed that the treatment with borate alone is very susceptible to mold growth in the block-stack condition, which has been known from borate diffusion treatments for many years (3). In some commercial practices, the mold control for borate treated wood has included both isothiazolinone based mold inhibitors and quat based additives. The test results of this study showed that addition of the three different quat compounds at levels up to 0.4% individually or in combination did not provide significant control of mold growth when in combination with borate treatment. The addition of mold inhibitor K1 at 45ppm provided good control for about 3 months at the test conditions used. The data demonstrated that the combination of K1/quat at 45ppm/0.2% effectively prevented significant mold growth for about 4 months for the borate treated wood. This suggests that potential synergism between two groups of chemicals may exist (6).

CONCLUSIONS

To simulate the conditions confronted by treated wood in block-stack situations, the green house mold test method report in this paper can provide valuable technical information to predict and thus guide the commercial practice on mold control during storage, retailing and installation.

The data reported here suggest that the different preservative treatment systems have their own mold resistance characteristics due to the chemical properties of the components in each type of treatment. The commonly used isothiazolinone based mold inhibitor K1 within the maximum allowable use level can provide good control of mold development for ACQ treated wood during the time when the wood is most venerable for mold growth, that is, just after treatment and during block-stacked storage. In some cases, such as with CA-C or borate treated wood, the combination of K1/K2 or K1/quat are needed for effective control of mold development after treatment and block-stacked during storage and distribution phase.

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