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WOOD PRESERVATION IN THE 2010's

BY

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Introduction

In 1975 I had the privilege of addressing this organization and express my views on wood preservative research needs and developments in the 80's. After a 30 year hiatus I have been invited to follow up on this and present my views on wood preservation in the 2010's. However, before I address future developments I believe it would be useful to briefly review the four major areas in wood preservation that I earlier expressed a need to receive greater emphasis in research priority.

The need for new wood preservative systems as a result of impending environmental regulations was discussed and it was predicted that some new wood preservative systems would be forthcoming. As we now know this prediction was accurate as CCA, penta and creosote have been restricted to industrial use and several new wood preservatives have been introduced into the market place. Notably are the amine copper-based systems. In addition some borate formulations are available and formulations based on triazoles and isothiazlones have been standardized.

The research in developing a waterborne penta preservative system was cited, with suggestions that this formulation would gradually replace the oilborne penta petroleum systems This prediction was obviously erroneous. As we all know now the waterborne penta system did not provide adequate protection, resulting in early failures of the treated wood products.

In the area of fundamental mechanisms of wood decay, some progress has been made. After considerable research the non-enzymatic wood decay mechanism employed by both brown-and white-rot fungi has been elucidated (Goodell, 2003) and considerable progress has been made in the area of fungal enzyme systems involved in the overall wood decay process.

With regard to improved test methods for evaluating wood preservatives, only limited progress has been made. We do have a few new test methods, but these still lack the ability to accurately predict the performance of new wood preservative system on a timely basis.

In the final area discussed concerning the need to develop practical methods for improving the treatment of refractory wood species, very little progress has been made.

Wood Preservation in the 2010's

I foresee several critical issues that will need to be addressed in the wood preserving industry in the next decade. These are:

- Development of treatments that improve the weathering of wood.
- Development of new organic wood preservative systems.
- Improved methods for evaluating the performance of treated wood products.

Weathering characteristics. In addition to the ability of wood preservative systems to protect wood from biodeterioration, the effect of treatments on weathering characteristics is of significance. Past experience with CCA treated wood used in decks and other structures indicates that the wood is protected from biodeterioration, but it ultimately fails as a result of severe checking, splitting, warping and discoloration. These negative characteristic of treated wood has stimulated the development of competitive products that contain high levels of plastic in combination with wood flour. Despite considerably higher costs, these products have captured a significant share of the residential decking market due mainly to their superior weathering characteristics.

In order to meet the challenge of these competitive products, the wood preserving industry will need to develop products that have significantly better weathering characteristics. One possible approach to this challenge is to produce radial face decking boards which have inherently better weathering characteristics (Sandberg and Soderstrom, 2006). Since it is not economocally feasible to obtain deck boards with radial face orientation using normal milling practices, alternate methods need to be developed. One potential method for obtaining radial face material from saw logs is to use the “Star Sawing” process developed in Sweden (Sandberg, 2006). This method produces fairly narrow radial face strips which must then be laminated together to produce deck boards of the desired dimensions. In addition, high quality water repellent/UV inhibitor treatments need to be developed to further improve the overall product. Although a product of this type would be more costly than the current decking boards, it should able to compete with the plastic/wood fiber products that sell for approximately 2.5 times that of solid wood.

Development of new organic wood preservative systems for soil contact. As indicated above, the wood preserving industry has undergone a major shift in moving from CCA to the arsenic-free copper rich wood preservatives. Nevertheless, there is still some concern about the potential effect of copper residues in the environment. As a result there is considerable interest in developing total organic wood preservative systems. Indeed, several organic wood preservative systems have been developed and recently introduced into the marketplace for above-ground applications. However, developing a similar product that is suitable for ground contact exposure will be more challenging.

One of the major issues involved in developing organic ground-contact wood preservatives is preventing biodegradation of the biocide(s). Penta is one example of an organic biocide that has been successfully used as a wood preservative for ground contact applications, but unfortunately has serious environmental issues. Although penta is susceptible to biodegradation in soil contact it still performs very well. However, penta is used at very high retention levels in comparison to the triazoles and other new organics. Furthermore, it is generally used with heavy petroleum carriers which contribute significantly to it’s performance. Unfortunately, the new generation organic biocides are considerably more expensive than penta which severely restricts the retention to levels that are cost effective. Consequently, the challenge will be to develop waterborne formulations that can provide reasonable performance at relatively low biocide levels.

Improved methods for evaluating the performance of treated wood products. In my opinion one of the biggest challenges facing the wood preserving industry is developing test methods that can predict the long term performance of treated wood products. As a result of economic and environmental issues wood preservation scientists are under increasing pressure to reduce the time required to develop data needed for standardization of new wood preservative formulations. In the past a requirement of about ten year field test data was considered acceptable, whereas today we are standardizing new preservative systems on the basis of 3 year's of field test data. This drastic reduction in data requirements is questionable and needs to be carefully evaluated.

Some progress in test methodology for evaluating wood preservatives has been made over the years, but it is limited and in my opinion current methods do not provide sufficient information in the relatively short term test time frame to predict the performance of new wood preservative systems. This deficiency relates to biodegradation of wood in both above ground and soil contact exposure conditions and will be addressed in detail later.

Soil block decay test. In evaluating new wood preservative systems the soil block test is the primary screening tool used to provide initial efficacy data for select brown and white-rot fungi. The results from this test are applicable to both above ground and soil contact exposure conditions. The value of this test in predicting long term exposure efficacy is limited because the data represents individual fungi in pure culture conditions. This is in contrast to the 'real world' where wood is subjected to a wide variety of microorganisms which interact synergistically in the biodegradation process. Furthermore, the inter laboratory results are extremely variable because of variable lab procedures as well as the soil and fungal strain effects on virulence (Hegarty, 1987, Leithoff et al., 1999, Richter et al., 2005, Smith and Gjovik, 1972 and Gray et al., 1991. Consequently, soil block laboratory tests are generally considered to have very little relevance in the overall scheme of evaluating potential new wood preservatives (McNamara, 1994).

In my opinion the soil block test is underrated and, with some major modifications, could possibly play a more important role in evaluating the long term performance of wood preservatives. Modifications that need to be made in order to achieve reasonable inter laboratory consistency relate to several changes in test methodology. These are:

- Use of a common soil substrate for all tests;
- Use the same fungal strains for all tests;
- Require that the fungi used in soil block test be re-cultured from wood periodically

In addition, some thought needs to be given to the possibility of using more than one fungus in the test. In this regard, recent tests in our lab have shown that considerably more decay was achieved with a combination of brown and white-rot fungi. In one study (Mangum, 2009) found that the level of decay was only half as great as *Gleophyllum trabeum* alone than when both *Trametes elegens* and *G.trabeum* were used in the test. Antagonism occurs with some combinations of fungi so studies are needed to establish compatibility. It may also be possible to incorporate bacteria in the test which would provide conditions more closely related to field exposure conditions.

Like all tests, however, the soil block has advantages and disadvantages. These need to be recognized and any modification necessary for a particular test made so that the results are appropriate. For example, in the AWPA E 10 soil block test, after inoculation the wood blocks can be immediately placed on the feeder strips, or the container inoculated for 2-3 weeks and the wood block then placed directly on top of the actively growing fungal mycelium mat. In the case where the particular biocide might be affected by the highly acidic nature of the fungal mycelium, the former option would likely give more realistic results.

Above ground exterior exposure tests. In general, the decay hazard for wood exposed above ground is significantly lower than it is for wood in soil contact. As a result wood products designated for above ground exposure are treated to lower preservative retention levels. Furthermore, different field test methods are used to evaluate the efficacy of these products. Presently, there are three AWPA standard tests that are designed for evaluating treated wood products intended for above ground applications. These are the L-joint test (E9) lap-joint test (E16) and ground proximity test (E18). The objective in these tests is normally to predict the performance of new or modified wood preservative formulations. Of these test methods the ground proximity test provides the most severe exposure conditions because the interface between the concrete and wood block remains wet for extended periods of time. This is in contrast to the other two test methods which tend to dry out fairly rapidly after rain periods.

A recent paper by Zahora (2008) provides an excellent review of his extensive experience evaluating several wood preservative systems using all three of the above ground test methods discussed above exposed at several test sites. His results show that many years of exposure is needed before the data can support a prediction of performance. Furthermore, he concluded that the rate of decay of untreated wood at various exposure sites is not a good predictor of the relative hazard to treated wood. This study, and my experience, suggests that the current AWPA guidelines suggesting that some indication of performance of preservatives can be obtained from three year data is way out of line. Consequently, we need either to require very long term exposure data from several test sites or greatly improve our test methodology before we can reasonably predict the performance of preservative systems.

One possible method of reducing the exposure time required to evaluate wood preservatives is to develop quantitative methods for evaluating the progression of wood decay. Presently, it appears that the most promising methods for evaluating the extent of decay in test samples are based on changes in the mechanical properties of wood. Of these methods, bending stiffness MOE and dynamic MOE show considerable promise. However, in order to use these methods appropriate test sample design must be considered. Accordingly, a lap-joint design that meets these requirements has been incorporated into the new proposed AWPA standard PEM 03. Although further analysis of these evaluation methods is needed, it appears that they will be extremely valuable in developing accelerated test methods.

All wood preservative biocides are susceptible to depletion as a result of one or more of the following mechanisms:

- Evaporation

- Water leaching
- Biodegradation of organics
- Complexing

Depletion of inorganic wood preservatives is limited to leaching or biological oxidation or reduction to a less bioactive oxidation state (i.e. Cu^{2+} can be reduced by some bacteria to $Cu^{1+)}$. Also, in some cases reacting with organic compounds to form inactive complexes. The depletion mechanism for organic biocides can involve evaporation, leaching or biodegradation. Once the biocide is reduced to a certain level the rate of biodegradation will accelerate. This suggests that detailed knowledge of the biocide depletion rate may be a critical factor to predict the performance of treated wood. In order to provide this information a fairly large number of depletion samples would be needed for a given preservative system so that the depletion rate can be determined by measuring biocide levels at regular intervals and to reduce the large depletion variation typically seen in individual stakes.

Another aspect of above ground testing is the extreme variability in decay rates of samples cut from different boards. Untreated samples from some boards will exhibit appreciable decay after one year's exposure, whereas samples from other boards remain sound after several year's exposure. Our studies have shown that this variation is due mainly to wood extractive content and permeability differences (Nicholas, et al. 2005 and Dahlen et al. 2009). One way to at least partially reduce the effect of this variability is to distribute the test samples from a given board across all treatments.

Ground contact exposure tests. For ground contact exposure there are two types of test methods that have potential for predicting the performance of new wood preservative systems. These are the accelerated soil decay tests (AWPA Standards E14 and E23) and the field stake test (AWPA Standard E7). With regard to the accelerated soil decay tests, in 1989 Ruddick published an excellent critique of the fungus cellar test method. In this paper he pointed out a number of deficiencies in this method which results in very poor correlation with field test results reported by Headley (1983), which result from our lack of knowledge on the basic biological, chemical and interaction factors that impact wood preservative performance. He suggested that we need to acquire an understanding of these variables and then develop an array of tests that could be carried out in a relatively short period of time to provide a realistic evaluation of a given preservative system. Unfortunately, very little research that addresses this void has been conducted, so we are faced with judging new preservative systems with very limited data.

Presently, data from field stake tests is considered to be the most important component of the efficacy data used to establish preservative retention levels and to judge the acceptability of a new wood preservative system. Although laboratory soil block and accelerated soil decay tests provide some useful information, field test stake data is paramount in the decision making process for determining the appropriate preservative retention level in order to insure a reasonable service life for the product. The current AWPA guidelines recommend that data from two different test sites with a minimum of three years exposure time be developed before field stake data is valid. However, there is a question as to whether three years exposure time is sufficient in order to predict the performance of preservative systems. In this regard, several recent studies (Lebow, et al., 2008, Schultz and Nicholas, 2009) seriously question the validity of using three year data to predict the long term performance of wood preservative systems. Consequently, on the basis of current field test methodology it is apparent that considerably longer field exposure data is needed before we can make reasonably accurate predictions of long term performance of new wood preservative systems.

Given the fact that current test methodology does not provide sufficient data that can predict the performance of alternate wood preservatives in a reasonable time frame, how do we improve our evaluation system? As pointed out above we obviously need to develop a better understanding of the overall decay process which involves complex interactions of bacteria and fungi, but this will require considerable long term research. Consequently, in the near term we need to concentrate on biocide depletion since it is one of the key factors influencing the service life of treated wood. All wood preservatives are subject to depletion from wood, with the rate dependent on the chemical composition and exposure environment. The current AWPA E7 field stake test standard has provisions for biocide depletion. However, insufficient details are provided in order to ensure that representative, statistically significant depletion data is obtained which can be used to track the biocide(s) depletion rate. Furthermore, no attempt is made to identify the mechanism of depletion which could be a major factor in determining the long term performance of a given preservative system.

As is the case for above ground tests, a more accurate method of detecting and measuring the extent of decay in field stakes is needed to replace the visual rating method. In this regard, both static bending and dynamic MOE methods have been evaluated (Grinda and Goller, 2005). In these studies the static bending method showed promise, but the fact that only one-half of the stake is exposed to the soil results in complications. Hence, additional work will be needed to fully evaluate this methodology. Another possibility for evaluating field stakes is the use of torsion strength. The possible advantage of this method is that it could be used with the conventional stake test specimen without the complications that are inherent for static bending. However, research is needed to fully evaluate this methodology.

Another factor that affects the service life of treated wood is soil chemistry, which can influence biocide depletion and the nature of microbial communities that can have a major influence on preservative performance. At present we know very little about the influence of soil chemistry on the performance of various wood preservative systems. As a result, it would be logical to conduct field stake tests at several different sites that have soil characteristics that would be representative of the soil environment that the treated wood is subjected to in commercial applications.

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