THE USE OF BUFFERED AMINE OXIDES FOR WOOD PRESERVATIVE TREATMENTS

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Summary

A buffered amine oxide preservative system has been shown to deeply penetrate wood and wood composites including a number of Canadian commercial species which are normally considered to be refractory. The buffered amine oxides act as carriers for fungicides, insecticides and other wood protectants. A description of buffered amine oxides is presented along with several examples of commercial applications of these systems around the world. An update is presented on Code acceptance of buffered amine oxide preservative systems and registration with the Canadian Pest Management Regulatory Authority (PMRA).

1. Introduction

Amine oxides have been used for many years as surfactants in consumer products such as shampoos, detergents and hard surface cleaners. Tertiary amine oxides consist of a nitrogen atom bonded to three alkyl groups and an oxygen atom. Typically, the alkyl groups consist of two methyls and a longer carbon chain moiety such as dodecyl. Amine oxides are considered to be polar molecules and are very weak bases. In neutral or alkaline solutions they exist in the non-ionic form and they behave similarly to tertiary amines.

$$\mathbf{RN(CH_3)_2 \rightarrow O \qquad\qquad R = C_{12}}$$

In the presence of acids, the coordinately bonded oxygen will accept a proton forming a charged or cationic molecule which is similar to a quaternary ammonium salt:

$$\mathbf{RN(CH_3)_2 \rightarrow O + H^+ \rightarrow [RN(CH_3)_2OH]^+ \qquad R = C_{12}}$$

The speed and completeness of this reaction will depend on the concentration of the protons present, i.e. the strength of the acid. Since wood contains acidic sites, one can treat wood with the non-ionic version of the amine oxide and expect that the conversion to the cationic form (quaternary ammonium salt) will occur in the use environment.

Buffers are aqueous solutions with highly stable pH values. They are usually made by mixing a weak acid with its conjugate base or a weak base with its conjugate acid. Some typical examples of buffer solutions are [sodium carbonate : sodium bicarbonate]; [citric acid : monopotassium citrate]; and [borax : boric acid]. When amine oxides are combined with buffers of the appropriate pH, they have been found to penetrate the wood much more rapidly and deeply than would be expected with unbuffered amine oxide systems. Moreover, the buffered amine oxides have been shown to enhance the penetration of wood protectant chemicals such as fungicides and insecticides into wood and wood composites. This discovery is the basis of a number of U.S. and international patents (Ward and Scott, 2010; Ward and Scott 2011; Ross and Cutler 2015) and has come to be known commercially as the TRU-CORE® Wood Protection System.

2. TRU-CORE® Wood Protection System

As noted above, the TRU-CORE® Wood Protection System is a unique, process based on buffered amine oxide technology that has been shown to deliver protectant ingredients deep into many species of wood and wood composites. For most species, full penetration of both sapwood and heartwood can be achieved without the use of aggressive pressure or vacuum treating protocols, organic based solvents, or high uptakes of water when it is used as the carrier (Ross 2013; Ross 2011; Ross 2010; Ross 2007; Ross 2006; Clawson *et. al*. 2013; Clawson and Cutler 2014). The buffering system helps to control penetration and binding in the wood. In most cases, borates are used as the buffers, but non-borate buffering systems can be used as well (Ross and Cutler 2015). The use of borate buffers has the advantage of providing additional biocidal activity to the system. Conventional biocides are incorporated into the buffered amine oxide delivery system and then applied to the wood substrates utilizing standard techniques such as dip, flood coat, spray and pressure/vacuum assisted impregnation. In the case of pressure/vacuum impregnation, cycle times and pressures have been shown to be significantly less than those typically employed with conventional treating systems. Biocides that have been utilized with the buffered amine oxide system include azoles, iodocarbamates, synthetic pyrethroids, neonicotinoids, solubilized copper and copper azole.

An important advantage of this system is that it imparts minimal amounts of water into the treated articles. For dip, flood coat or spray application methods, water uptake is on the order of 3% (m/m). Full penetration of active ingredients by the substrate is typically achieved after a 12-24 h activation period. When pressure/vacuum assisted treatment methods are used, mass uptakes for the buffered amine oxide system are typically less than 25% (m/m). This compares to typical water uptakes of 100-150% (m/m) for conventional pressure/vacuum assisted treatments. The main consequences of these low water uptakes are that there is no need for post-treatment drying and no adverse effects on the appearance and mechanical properties of the treated articles. This allows the post-fabrication treatment of wood composites such as OSB, LVL and I-joists which would not normally be possible using conventional water-based treatments (Ross 2013).

3. Applications

As of early 2016, there were over 50 commercial treating programs utilizing the buffered amine oxide technology for delivering wood protectants. Programs include the preservation of framing lumber, exterior trim and siding, millwork, fencing, engineered wood, I-joists, railroad crossties and decking. These applications have been reviewed in detail (Clawson and Cutler 2014). The first use of the technology came in New Zealand in 2004 in response to the massive “leaky house” crisis that accounted for over $11 billion (U.S.) in damage caused by subpar building practices (NZ DBH, 2004). The increased moisture content in these structures resulted in optimal conditions for growth of decay fungi and mold. In response to this crisis, the New Zealand government developed a new building standard requiring that all residential structural lumber be treated to impart fungal protection (NZ Standard 3640, 2004; amended 2013). This event was not unique. A similar "leaky condo crisis" occurred in coastal British Columbia in dwellings built during the 1980-2000 period. The TRU-CORE buffered amine oxide technology was used in New Zealand to meet the requirements of Hazard Classes 1.2 and 3.1. Borates, in addition to being the buffering agent, also serve as the principal fungicide in this system. More recently, this technology was successfully adapted in Australia for borate treatment of wood used in Hazard Classes H1 and H2. Due to the prevalence of termites in most of Australia, an organic insecticide is utilized to impart further termite resistance. Baltic pine, mixed pines and eucalyptus species are being treated. Full penetration of these products (including the heartwood) has been documented by independent experts (Ahmed and French, 2011).

In the U.S. the buffered amine oxide technology is being utilized to deliver azole-based fungicides and synthetic pyrethroid- and neonicotinoid-based insecticides into lumber used for primed siding, fascia and trim board. The system is applied by spray or flood coat via in in-line treating system. After a brief activation period during which the active ingredients have fully penetrated the substrates, the articles are primed via an in-line coating system. The full penetration eliminates the need to retreat cut ends in the field. Siding and trim board products protected using the TRU-CORE system are sold in many of the "big box" home improvement stores in the U.S. and Canada.

Wood window and door manufacturers in the U.S. and Canada have historically used solvent based preservative systems to treat wooden millwork components. The solvent carrier (usually mineral spirits or VM&P naphtha) promotes good end grain penetration of the preservatives and rapid dry time for treated parts. However, concerns over costs, flammability and solvent emissions have encouraged many manufacturers to consider water based treating systems. The TRU-CORE system provides excellent penetration of active ingredients with a low mass pick up (typically 2-3% m/m) of treating solution. The penetration is accomplished without grain raising or loss of dimensional tolerances and it does not require a post-treatment drying step. Since the system is water-based, solvent emissions are significantly reduced over conventional systems. A number of U.S. based manufacturers are adopting this system, while Canadian producers await approval from the PMRA.

A highly advanced buffered amine oxide treating system was developed for the world's largest treater of railroad crossties. This technology allows cost-effective implementation of a dual treatment process with borates and creosote (Ross 2010). To date it has been used to treat over 20 million ties.

These are just a few examples of the commercial use of buffered amine oxide programs to treat wood and wood composites used in the home, on the home, around the home and in industry.

4. Code and Regulatory Acceptance

As noted above, the TRU-CORE buffered amine oxide treating system has successfully met the requirements of Hazard Classes 1.2 and 3.1 of the New Zealand residential building code and Hazard Classes H1 and H2 of the Australian code. In the United

States, the International Code Council Evaluation Service (ICC-ES) issued an Evaluation Report (ESR-3539) in 2015 verifying that the TRU-CORE Type 1 Wood Protection System meets the requirements of the IBC and IRC building codes for durable wood protection against fungal decay and Formosan subterranean termites. ICC-ES is a subsidiary of the International Code Council (ICC) and is the United States' leading evaluation service for building products, components and systems. In Canada, as of early 2016, the Pest Management Regulatory Authority (PMRA) is in the process of evaluating the registration of the amine oxide component of the TRU-CORE system for use as an adjuvant with the wood preservative components (which are already registered in Canada).

5. Conclusions

The TRU-CORE Wood Protection System, based on buffered amine oxide technology, is a chemically-based infusion process shown to transport key wood protectant ingredients deeply into wood and wood composite substrates. The borate buffers often incorporated into this system have also been shown to enhance the fungicidal and insecticidal performance of the other active ingredients utilized. The system can employ dip, spray or flood coat application methods; for larger materials pressure and vacuum assisted methods can also be used. The low mass pick-ups associated with these application methods result in substrates having significantly improved dimensional stability, mechanical properties and surface appearance compared to conventional treating methods. Major efficiencies have been realized with this process due to these low volume uptakes, eliminating the costly time and energy-consuming step of post treatment drying. The system has been in commercial use for over ten years and is employed in a variety of applications to treat wood used in the home, on the home, around the home and in industry. It has achieved regulatory and code acceptance in the United States, New Zealand and Australia and is currently awaiting regulatory approval for use in Canada.

6. Literature

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