CWPA Proceedings, 2004, pp 33-47

FRAMING STAGE TREATMENTS IN THE USA

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Summary

The environmental benefits of using wood over non-wood construction materials and of conserving worldwide timber resources combined with biological deterioration problems found in the field, point to the need to find improved methods of protecting structural lumber.

This paper reviews the current problems in construction caused by biodeterioration in the USA and how these can be (and are) simply and cost effectively overcome by framing stage treatments. Whilst the majority of wood in US construction is protected by indirect chemical applications to the soil, there is a growing trend for direct applications to the wood and a recognition that such approaches can target all problem organisms as well as effectively overcome the inventory and supply issues faced by using industrial or factory applied treatments.

Borate technologies lead in the area of framing stage wood treatments, and the benefits of these as well as current practice and experience is reviewed. Up to 60 years of global experience with borates and 15 years with *in situ* application in North America demonstrate that borates offer proven efficacy against a range of wood-destroying pests, application flexibility, protection that can last as long as the wood remains in service, and a good margin of safety to humans and the environment. The benefits of borate treatments can be combined with specific organic fungicides to add mold performance to the list of wood destroying organisms that the borates prevent.

Finally, available products in Canada are listed with a brief opinion as to which could potentially be used to solve current Canadian problems and add value to existing exports.

Biodeterioration Problems

The major wood destroying pests of the United States have been well documented. They include a variety of species of wood decay fungi, subterranean termites, drywood termites, wood destroying beetles and carpenter ants, probably in that approximate order of importance. However, geographic location shifts the importance of each group of organisms significantly, largely dependant on temperature and annual precipitation. For details of each group of organisms, their significance, geographic distribution and their identification the reader is directed to Smith & Whitman (1992). For an idea of the degree of biological hazard in a given region, the reader is directed to the US ‘Deterioration Zones’ given by AWPA (2003).

In summary though, subterranean termites are thought to do at least $2 to $4 billion US damage per year. Anecdotally, it is often said that termite damage is greater than all the flooding, hurricane and tornado damage in the US combined. Fungal decay is thought to be even more damaging (although it is much less widely recognized). Smith and Whitman (1992) projected >$17 billion US for 2000, for fungal decay.

Traditionally, construction practice has tried to deal with the level of hazard in a variety of ways, normally mandated by local or national building code. Susceptible wood species used in framing in the East must be supplied to the job site at 19% moisture content (kiln dried), sill plates must be pressure treated according to AWPA standards, including the treatment of field using an end cut treatment (especially important with western species and heartwood of other species). Florida and Hawaii as well as many mortgage lenders in states with a high termite hazard, and the new Residential Building code, all require a termite treatment or barrier of some sort.

However, every home built is built outside, and for much of the time, the ambient climatic condition can play a big role on the success of such approaches. It is rare in the Southeast for wood to actually have a moisture content less than 25% (so susceptible to mold and decay and open to drywood termite and wood destroying beetle infestation initiation) by the time it is incorporated into a home. It is also not very practical for builders to do field treatments, and legally, pesticides (including end cut preservatives) have to be applied by a certified pest control operator. In reality, most homes never receive proper treatments, so technically, they are not built to code.

The traditional type of treatment used to protect the majority of construction lumber from biodeterioration is actually a soil treatment which is applied to the soil under a house and not applied to the wood at all. Soil treatments using persistent insecticides proved successful at preventing at least subterranean termite attack and they were used for many decades. With the demise of Chlordane for environmental reasons in 1987 and the current demise of chloropyriphos, the market has proliferated with a variety of options. These together are generally referred to as 'Termite Pretreats' and include non-repellent soil termiticides, repellent soil termiticides, baiting systems, physical barriers and chemical barriers applied in the structure (the latter being mainly to wood). Approximately 500,000 of such pretreats are done each year. Weather again has an important impact. Soil treatments have to go down immediately before pouring a slab foundation and are compromised by rain or wet ground (probably more than half of them in Florida for example?). Yet a further problem in some states is the lack of proper policing by underfunded regulators. Many treatments are therefore not carried out according to label and could be deemed to be fraudulent. If this weren't enough, even if a termite barrier treatment were to be applied absolutely perfectly, it still has no performance whatsoever against wood decay (a bigger problem than termites) drywood termites, wood destroying beetles, carpenter ants or mold fungi, all of which can blow or fly or crawl into almost anywhere within the home.

It is due to the combination of these problems that framing stage wood applications are now fairly widespread and are growing rapidly.

Framing Stage Wood Treatments

Many wood preservatives have been successfully applied by topical processes. For construction timber, the straight dipping of lumber in Europe has been widely practiced. Borate dips (10 % disodium octaborate tetrahydrate (DOT)) have been used under DIN 68-800 in Germany, protecting framing from decay and insects for 30 years; pyrethroid insecticides have been used to protect roof trusses from beetles such as *Hylotruppes bajulus* under the CTBA B+ scheme in France and in the UK, light organic solvent treatments, borates and aqueous emulsions applied by double vacuum or immersion have been used for as long. Topical treatments are also the norm in the US for exterior window millwork/joinery and are being adopted in Australia for protecting framing from termite attack. Pest control operators and remedial treaters around the world have also carried out successful wood treatments using topical *in situ* applications.

It has been a simple step to combine the technologies of topical industrial pretreatments with *in situ* remedial treatments to come up with highly efficient and efficacious *in situ* preventive treatments applied during the framing stage of construction, especially using the diffusing borate based technologies.

Borates

The broad spectrum activity of borates against both microorganisms and insects has led to their extended use in biodeterioration control and wood preservation. Boron compounds are used as fungicides, algaecides, bactericides and insecticides (Merck Index 1976), with their use in wood preservation being effective against both fungi and insects.
In general, borates have been proven effective against all known wood destroying organisms; the data is extensive and cannot be covered in full here. For a comprehensive picture, the reader is directed to the reviews of Carr (1959); Cockroft and Levy (1973); Barnes *et al*. (1989); Dickinson and Murphy (1989), Drysdale (1994) and the work of Manser and Lanz (1998).

Dickinson and Murphy (1989) drew attention to the success of borates in the *in situ* treatment field, particularly with the developments and extended use of solid boron rod systems and the glycol borates (Bechgaard *et al*., 1979; Dicker *et al*., 1983; Beauford and Morris, 1986; Beauford *et al*., 1988; Henningsson *et al*., 1989) in Europe. The glycol borates are recognized as superior to most alternatives and are used widely in the remedial industry in specialty areas where little else is suitable. The relative success of borates in this field has led a number of companies to market borate-based products in other parts of the world. Specifically, formulations based on disodium octaborate tetrahydrate (DOT) have been most prevalent, and *in situ* pre-treatment as well as remedial application is now widespread in the USA and elsewhere.

Of interest to the industrial pretreatment industry in both the USA and Canada, are the very high standard retentions used. In non termite hazard areas or where other forms of termite protection are given, the retentions used are about many times higher than they need to be. This can be seen easily in the biological reference values determined according to EN 599 (table 1).

Aside from efficacy, one of the attributes of using borate-based systems is their very low acute mammalian toxicity and low environmental impact. The environmental effects of borate have been reviewed extensively (ECETOC, 1996). It was concluded that "Boron is a ubiquitous element, present naturally in sea water, fresh water, rocks, soil and all plants. Boron neither accumulates in any environmental compartment nor bioaccumulates, but is transported into the oceans which have a high natural environmental background level of borate. Boron is an essential micronutrient for the healthy growth of all plants, and boronated fertilizers are used in agriculture to improve yields and to correct the symptoms of boron deficiency in crops. At the concentrations generally monitored in river water, borate causes no adverse effects to either land plants by irrigation or water plants and aquatic life. Similarly, borate levels generally detected in soil cause no effects to land plants or soil organisms. Organisms in fresh water are the most sensitive to borate. The safe no effect concentration (NEC) of borate to all freshwater aquatic life is at least 1 mgB/l". Ecotoxicity data has been given in Table 2**.**

Boron toxicity to animals and humans has also been reviewed in detail (Data also given in Table 2). It has been concluded to be of low toxicity with a tolerable daily intake of 24 mg B/day (IEHR 1995; ECETOC 1995; Murray 1995; WHO, 1998). Potential hazards in humans and mammals are avoided by dilution (size effect) and by rapid and almost immediate excretion via the kidneys.

As mentioned previously, borates are diffusible preservative systems. This is a considerable asset for remedial treatments where the active ingredient needs to get to the pest organism, but is also of importance for preventive treatments against fungal decay. It does not appear to be important for preventive treatments against insects.

A body of data provides a profile of the relationship between wood moisture content and diffusion into the wood. The data shows that while wood remains dry (<15%), topical treatments do not allow penetration to the same degree as is achieved with pretreatment of lumber by pressure processes. Various workers have looked at this and concluded that penetration from 2 to 10 mm is achieved, and that this envelope is protective against termites and other insects (Robinson and Barlow, 1995; Mampe, 1997; Williams, 1997; Potter, 1997; Williams and Grace, 1997).

Wood having a moisture content of 16-18% under a 50% relative humidity is representative of household conditions encountered during the summer and fall in the eastern and southeastern United States. Relatively dry wood with 8-10% moisture content and in a low relative humidity is representative of the household conditions during the winter and early spring in the same area (Bois, 1959). At moisture contents above 15%, borates utilize this natural moisture in the wood to diffuse deeper over time, (Schoeman, 1998). Of course, in a preventive situation such penetration as has been discussed is only needed for fungal decay performance. Wood moisture content needs to be at a minimum of 25% to be susceptible to fungal decay though. So, if wood gets wet enough for fungal decay, the borate is mobilized and will eventually provide full penetration, protecting even the middle of the wood from decay.

Experience & Current Practice

As previously mentioned, the majority of lumber used in the US that has any additional protection applied to it (other than simply keeping it dry and above grade) is protected by indirect treatments to the soil. The protection is only for subterranean termites and, as it is not a direct application to wood, will not be dealt with further here.

Wood applied framing stage treatments then fall into three discreet applications or markets:

1. A toxic termite barrier (Termite Pretreatment) that is replacing traditional soil treatments. A 40% DOT glycol borate (available commercially as Bora-Care®) is diluted with water to a 23% DOT concentration and applied by spray to wood, concrete and other materials to a height of 2 feet as a termite barrier (Plate 1).

2. Treatment of the entire structure (Whole House Preventive Treatment) to prevent all wood destroying organisms (fungal decay, wood destroying beetles, carpenter ants, and drywood termites but not used as a termite pretreat as above) (Plate 2).

3. Treatment of the entire structure to provide protection of mold (Whole House Mold Treatment) using moldicides or mildew resistant coatings.

Probably the most widely adopted framing stage wood treatment is the glycol borate Termite Pretreatment. Approximately half of new homes built in the USA have a termite pretreatment applied to them, and approximately 15% (and growing rapidly) of these receive the wood application. To date over 200,000 homes have been protected with this system. The advantages are very clear: for the applicator (only one visit to the house instead of two or three is needed); for the builder (no rain delays, contractors do not have to be off site for 24 hours and the sill plate end cut requirement is met, so the house meets code); for the regulators (very easy to see the application and to do regulatory QC); and for the home owner (who gets a treatment that is verifiably to label, provides some decay as well as termite protection, is backed up by a 5-year damage repair warranty and is a treatment that is permanent rather than one that breaks down in the soil over a 5 year period). The fact that 2 to 3 gallons of material is used on the base of a structure rather than 400 gallons used in the soil under the structure also has some environmental benefits.

Of course, in Canada, the primary concern is not with termites, but with the other wood destroying organisms (especially fungal decay) and mold. In the USA, the first whole house *in situ* treatments were successfully pioneered by US Borax over the last 15 years with their Tim-bor® Insecticide (DOT) treatment (now Tim-bor® Professional). They focused on this treatment as an alternative to untreated lumber or steel frame construction. Treatments are now widespread and, especially in California, are carried out extensively on new construction to prevent drywood termite attack (without such treatment, wood homes typically require a tent fumigation at each purchase or approximately every 10 to 15 years). The label requires an application of 15% DOT in water and is applied to run off. Such treatment also prevents fungal decay, wood destroying beetles and carpenter ants, and really, its only negative is the unstable solution concentration used and the high volume required in the structure. As an alternative, the glycol borate product label allows for dilution down to 8.5% DOT and is applied at approximately half the liquid volume as the straight DOT in water. As a result it is gaining acceptance, especially in California and Florida – again mainly for drywood termites, but it is also labeled to prevent all wood destroying organisms, including fungal decay. The glycol is seen to boost both penetration at low moisture content as well as efficacy against the target pest.

With the recent increase in public and builder awareness regarding the potential health effects of superficial mold and mildew fungi (non-decay fungi), demand for mold protection and for reduced potential builder liabilities has led to demand for mold treatments. The borates by themselves, whilst somewhat effective at the high concentrations used, are not as effective as some specific organic fungicides and are generally not labeled for mold applications. It was a simple and easy step to add an additional active ingredient to the borates already in use to strengthen this area and now approximately half of the Whole House Preventive Treatments are done for both wood destroying organisms and mold. DDAC (available commercially as Mold-Care®) is the widest used professionally applied material, although chlorothalanil, propiconazole and IPBC, as well as other quats are found in the field. All these materials are also synergistic when used with borates and most are surface-fixed providing higher surface efficacy compared to the penetrating borates, making the combination of the two ideal. USDA tests have recently compared borates with and without both DDAC and chlorothalanil in their ability to control common health effect fungi, including *Stachybotrys* on both wood and sheet rock (Michales *et al*., 2004).

The last category of treatment is the mold-only treatments. Generally these come with a ‘buyer beware’ label, and it should be noted that the views here are the author’s opinion only. US EPA requires registration for any product that makes a kills or prevent claim. This includes kills or prevents mold. Many companies are currently selling mold treatments that are basically paints with a registered film fungicide or in-can preservative in them. They are arguably effective in preventing surface mold, but when sold as mold treatments, the finished formulations applied should legally be registered as pesticides with the EPA (and they are often not) and applied only in accordance with their labels. In addition to this, state laws require that pesticides be applied by certified pest control professionals with appropriate training and insurance, etc. Many of the ‘mold paint’ type products are being applied by general contractors, which, again, is not legal. Besides the legal angle, there is also a technical one. These products offer no protection from fungal decay, but the lay person and final customer is not aware of the difference. When applied to wood of a high moisture content or even to dry wood that subsequently gets wet, they will retard drying and can actively promote fungal decay and potentially, therefore, structural failure.

Opportunities for Canada

'Leaky Condo' syndrome leading to severe fungal decay and mold growth in structures in Canada has again heightened the awareness of the general public to the bio-susceptibility of wood when used as a construction material. It can be argued forever that when a home is designed correctly, built correctly and maintained correctly, wood is not at risk of biological attack and remains by far the best construction material available. However, with the billions of dollars of damage every year in the USA alone, it can also be argued that for whatever reason, it appears impossible to always design, build and maintain our homes correctly. For this reason, an appropriate treatment should be added into the design and specification of wood construction. It can also be argued as to the pros and cons of various active ingredients, as well as various application methodologies from pressure treatment to dip treatment to *in situ* framing stage treatments. However, almost any treatment is better than none, and non-wood competitive materials are currently taking advantage of the lumber and construction industries' lack of action. Steel framing and concrete block have replaced much of the traditional wood construction in both Hawaii and Florida (not to mention the rest of the world), and insulated concrete forms are also on the increase.

The major opportunities here for the Canadian industry appear to be two-fold:

1. Recognize the incredible actual performance that has been seen with topical treatments and adopt either an *in situ* framing stage treatment or a topical pretreatment to solve current problems in Canada.

2. Recognize the ease and cost effectiveness with which topical treatments can be done as a pretreatment in Canada, and offer the option to the US market to add value and reduce liability to current exports.

Topical treatments have proved more than adequate for framing lumber for many decades in many parts of the world. Using this experience, we can see that a number of the products currently available in Canada could potentially be used to realize these opportunities (table 3).

New formulations and labels can be prepared, but there are already some good options available. Just by way of example, if all construction lumber were dip treated with F2 after finishing, or if we carried out an *in-situ* application with Boracol 10-2, the current – and many of the future – problems of wood biodeterioration would be mitigated.

Conclusions

Framing stage treatments can be specifically formulated to target all relevant target pests. The leading treatments carried out today have been well proven in both the US market as well as in many other parts of the world over many decades.

One of the major advantages with this type of approach is its flexibility. It can be easily offered as an option by builders to potential homeowners and can be specified in at the last minute. It is also relatively easy to treat all susceptible materials, as they are all present on site at time of treatment. This overcomes the major inventory disadvantage of treatments carried out earlier in the supply chain. *In situ* treatments also are highly cost-effective and ‘piggy-back’ the mandatory termite treatments or sill plate end cut treatments that require a licensed pest control professional to be on site anyway.

Industrial pre-treatment using topical applications could also provide just as good a level of protection and would likely be much more commercially successful than trying to do unnecessary and expensive pressure treatments and re-drying of construction lumber.

Borates are well-proven wood preservatives of low acute mammalian and environmental toxicity. They have found extensive and effective use in industrial and *in situ* timber protection and pest control applications throughout the world, and have now proven to be one of the best approaches used in framing stage treatments to protect construction lumber in the USA. While borates, and especially glycol borates are effective at controlling all wood destroying organisms, surface mold fungi tend to be less susceptible, and high borate surface loadings are needed to deliver successful control. An alternative and probably more effective approach is to combine specific organic moldicides in borate formulations. Effective chemistries include DDAC, IPBC, CTL, Azoles and combinations there of. In addition to the advantage of an increased broad spectrum, such combinations are normally synergistic in their performance. Recent experience regarding the use of framing stage treatments and the practical benefits gained from commercial applications show that they will play a significant role in the future protection of timber in the USA, and that they could play a similar role in Canada.

Canadian lumber suppliers could use this experience both to solve existing problems in Canada and to add value to current exports. Of course, adopting either a cost-effective topical pretreatment approach or an *in situ* framing stage treatment to protect the home from the problems we see today can only help with the long-term reputation of wood as a sustainable building material and further justify its continued and expanded use.

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Table 1

Biological reference values for DOT

Test	**Organism**	**BRV**
EN 113	*Coriolus versicolor*	0.76 kg/m^3
EN 113	*Gloeophyllum trabeum*	0.59 kg/m^3
EN 113	*Coniophora puteana*	0.32 kg/m^3
EN 113	*Poria placenta*	0.30 kg/m^3
EN 49-1	*Anobium punctatum* superficial treatment	8.53 g/m^2
EN 49-2	*Anobium punctatum* penetrating treatment	0.30 kg/m^3
EN 47	*Hylotrupes bajulus* penetrating treatment	0.69 kg/m^3
EN 20-1	*Lyctus brunneus* superficial treatment	5.55 g/m^2
EN 20-2	*Lyctus brunneus* penetrating treatment	2.07 (1)* kg/m^3
EN 118	*Reticulitermes santonensis* penetrating treatment	5.55 kg/m^3

*1 kg indicated by other data.

Table 2

Health and Environmental Safety Margin of Disodium Octaborate Tetrahydrate

Acute oral LD_{50} (rats)	2,550 mg/kg of body weight
Acute dermal LD_{50} (rabbits)	>2,000 mg/kg of body weight
Acute LC_{50} (rats)	>2.0 mg/L
Tolerable Daily Intake (humans)	24 mg B/day
Probable Daily Requirement (humans)	>1 mg B/day
IARC carcinogen	DOT not listed
NTP Biennial Report on Carcinogens	DOT not listed
OSHA carcinogen	DOT not listed
Carcinogenicity/mutagenicity	No evidence in mice (boric acid)
Reproductive/developmental toxicity	High dose animal feeding studies in rats, mice and dogs demonstrated effects. A human occupational study showed no adverse human effect on reproduction. Independent reviews conclude no risk associated with normal handling and use.
Sensitization	DOT is not a skin sensitizer
Eye irritation	Mild eye irritant in rabbits. Not considered a human eye irritant in normal industrial use.
Skin irritation	Non-irritant to intact skin
7-day LC_{50} (Goldfish) *Carassius auratus* (embryo-larval stage)	65 mg B/l (sodium tetraborate)
3-day LC_{50} (Goldfish) *Carassius auratus* (embryo-larval stage)	71 mg B/l (sodium tetraborate)
24-day LC_{50} (Rainbow trout) *S. gairdneri* (embryo-larval stage)	88 mg B/l (sodium tetraborate)
32-day LC_{50} (Rainbow trout) *S. gairdneri* (embryo-larval stage)	54 mg B/l (sodium tetraborate)
96-hour EC_{50} (Green algae) (*Scenedesmus subspicatus*)	24 mg B/l (sodium tetraborate)
24-hour EC_{10} (Daphnids) (*Daphnia magna straus*)	242 mg B/l (sodium tetraborate)
Persistent/degradation	Boron is naturally occurring and ubiquitous in the environment, and is dispersed to natural levels through dilution.
Soil mobility	DOT is soluble in water and is leachable through normal soil.
Phytotoxicity	Boron can be harmful to boron sensitive plants at high concentrations. However, boron is an essential micronutrient for healthy plant growth.

Table 3

Relevant Registered Products Available in Canada

Reg #	Registrant	Product Name	Active	Claim
18266	Home Hardware Stores Ltd.	Home Brand Clear Preservative	Zinc-2%	Rot, mold, fungus, mildew, decay, insects
18879	US Borax Inc.	Tim-Bor Industrial	DOT	Decay, fungi, insects
21324	Wood-Slimp GMBH	Impel (Boron) Rods	DOT	Fungal decay and insects
21753	Kop-Coat Inc.	Kop-Coat NP-1	DDAC & IPBC	Blue stain, mould, decay
21939	Arch Wood Protection Canada Corp	F2	DOT & DDAC	Stain, mold decay
24091	U.S. Borax Inc.	Tim-Bor Insecticide	DOT	Decay fungi, insects
24134	Janssen Pharmaceutical Products L.P.	Wocosen's Wood Preservative	Propiconazole	Decay, molds
24246	Everdry Forest Products Ltd.	Dryvac 1010	Propiconazole	Decay, molds
24493	Wood-Slimp GMBH	Boracol 20-2	DOT	Fungal decay, insects
25580	Genics Inc.	Cobra Rod	DOT Cur & BA	Fungal decay, insects
25664	Wood-Slimp GMBH	Boracol 20-2 BD	DOT & DDAC	Mold, fungal decay, insects
25665	Wood-Slimp GMBH	Boracol 10-2	DOT & DDAC	Mold, fungal decay, insects
25696	Kop-Coat Inc.	Woodlife F	IPBC	Decay, molds
26250	Mason Chemical Company	Maquat SSC	DDAC	Mold, fungus
26430	Sashco Inc	Penetreat	DOT	Decay fungi, insects

Plate 1

Framing Stage Two Foot Band Glycol Borate Subterranean Termite Barrier Treatment
(applied with blue marker dye to wood, slab and other areas)

Plate 2

Framing Stage Whole House Preventive Treatment with Glycol Borate and Moldicide