GLOBAL STATUS OF WOOD PRESERVATION RESEARCH AND DEVELOPMENT

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1. Introduction

Wood preservation research is influenced by the structure of the industry, the trends occurring within the production and use of treated wood, funding opportunities and performance requisites. Wood preservation research has many positive attributes, and a few negatives. The positives are a strong global research community in the form of the International Research Group on Wood Preservation (IRG), a relatively low technology with limited capital requirements, and a multi-disciplinary science blending biology, chemistry and engineering. There are a wide range of opportunities particularly in respect of protection of new wood-based materials and environmental science and engineering. The negatives are a relationship with a traditionally conservative industry, the forest products industry, that has in the past shown a disinclination to change, an industry with generally low margins that discourage innovation and R&D spending, technology development and affirmation lead times which are extraordinarily long by the standards of most industries, and a perceived reluctance to believe that change can provide positive benefits.

2. Discussion

These are undoubtedly times of change for research in the field of wood preservation. Product development research is not growing and may even be declining somewhat, while research into environmental fate and performance of existing products is clearly growing. Ten years ago, the International Research Group on Wood Preservation did not have a Section on Environmental matters, but Section 5 of this organization is now one of the larger areas of interest. Conversely, the Section on Marine Preservation has disappeared and papers on marine applications for wood preservatives are now relatively few and far between. These two trends are undoubtedly linked, with concerns about the environmental impact of wood preservatives in the marine environment having a negative impact on the use of and further development of such treatments.

There are many organizations involved in wood preservation research, including the CWPA and the AWPA here in North America, but membership of both of organizations is, at best, static and in the case of the AWPA has seen a declining trend over the last 10 years. Partly this is due to consolidation and changes in the industry, which have impacted the number of people involved, but it may also be a reflection of the success of the IRG organization in becoming the predominant force in communication for wood preservation research, development and technology. Undoubtedly, the ability of the annual IRG conferences to attract a critical mass of interested and involved scientists and technologists in this field, has led to its continued growth and probably as a consequence, negative impacts on other technical forums in this field.

2.1 Biological Research

The preponderance of research in wood preservation continues to lie in the area of the biology of biodeterioration. In the fungal decay area, new and advanced techniques for fundamental analysis and characterization of biological processes, e.g. PCR, immunogold and other labeling techniques, confocal microscopy, genetic engineering, etc. are being advanced and progress continues on trying to understand fungal mechanisms, especially in regard to brown rot decay. Work also continues on the physiology of decay, advances in early stage fungal detection and in fungal differentiation techniques. With the increasing use of copper-based preservatives in Europe, Japan and elsewhere, there has been renewed interest in the role and significance of copper tolerant fungi in regards to impacting preservative performance in service.

Biocontrol research for wood protection remains largely at the fundamental research stage. For long-term broad applications, success is likely to be hampered by the multiplicity of organisms encountered during a treated product's service life, and successive fungal challenges. Some research success has been achieved with specific sapstain applications, but widespread use of the concept in long-term wood protection still appears to be a distant goal.

After something of a hiatus, there has recently been considerable research activity in the entomological aspects of wood preservation. This is particular true in North America, Japan and Australia, although research continues elsewhere. Fundamental aspects are focused on the biology of termites, pheromone chemistry and its use in control methods, behavior effects on control vectors, test methodology appropriate to behavior and life cycle, the impact of termite species on preservative thresholds and natural durability mechanisms and potentials. The applied research in Australia is driven by recent changes in the type and use of soil applied insecticides, leading to a need, perceived or real, to treat framing lumber in structures. The North American research is driven by the spread of the Formosan termite through southern regions of the U.S., and a belated awareness of the potential damage this termite presents. In Hawaii and Japan research is also targeted at the Formosan termite but more in relation to finding effective treatments for the inherently more difficult to treat wood species used in construction in both countries. As is often the case, differences of opinion exist as to the performance of certain preservatives in regards to treatment needs and practices, as well as actual performance in the wood species being used. From the Canadian perspective, the question remains as to whether a suitable combination of treatment and effectiveness can be attained for SPF, Hem-fir and Douglas fir that would allow these species to be used with impunity in regions of high Formosan termite hazard. Clearly, this question should not be resolved lightly given the liability potential involved.

2.2 Sapstain

An important aspect of the wood protection lexicon is the area of sapstain and its prevention. Research continues to provide information on fungal populations and succession in the biodegradation of raw lumber, while other fundamental research focuses on the role of insect vectors in sapstain development and on biological control possibilities for pigmented sapstain disfiguration of wood. It is fair to say that most research on sapstain continues to involve testing of new fungicidal chemicals and/or formulations, activities that tend to be wood species and geographical location specific. In a shrinking world, however, it is apparent that the European Biocide Directive will likely have a major, and chilling, impact on future actives and formulations used in sapstain treatments globally.

2.3 Ancillary Areas

Analytical chemistry in wood preservation is growing, and will continue to assume greater importance, due to increasing environmental tracking needs and the move towards organic biocide containing preservatives, and this is the case for both fungicides and insecticides. Advances in HPLC technology allow for the simultaneous analysis of multi-component organic preservative systems. Also, newly advanced portable x-ray fluorescence techniques allow for the analysis of preservative concentrates, working solutions, and wood retentions. This technique also shows promise for the analysis of some of the newer organic biocides in solution and wood, in a manner similar to, but in advance of that previously developed for pentachlorophenol. One area where we have had success is in developing analytical methods for the quantification of hydrocarbon wax water repellents in wood preservation. These techniques include rapid quantification of working solutions containing emulsion water repellents through turbidity measurement techniques, and quantification of wax and oil hydrocarbons in treated wood through fourier transform infrared spectroscopy. Provided third party quality assurance schemes remain as a foundation of product quality in the wood preservation industry, at least in some countries, then analytical chemistry will remain and grow as an important tool.

One area that is seeing a surge of research interest is in the protection of wood-based composite products. Several factors appear to be driving developments in this area. One is for protection of composites from Formosan termites in board applications in the US south. A second is that as the markets for composite board products become saturated and commodity driven, so too companies are seeking ways to differentiate their products, and biodeterioration protection is one such avenue. A third factor is that as newer applications for composites are developed, these increasingly are in situations where biodeterioration in service is more likely to be encountered. As the move to more efficiently utilize wood fiber grows worldwide, so does the use of composite materials as replacements for solid lumber. In many instances the wood composites are more prone to moisture changes and accompanying biodeterioration potential. Against this backdrop, providing protection against biodeteriogens appears to be a prudent move.

2.4 Environmental Drivers

In Europe the drive to reduce chemical loads in the environment has been changing the use of wood preservation for the last two decades, initially in northern Europe but increasingly throughout the region. This drive often appears to provide little recognition of the negative impact this may or is having on treated product performance, or after the fact stimulates a lowering of product longevity expectations that seem to be accepted by most consumers. There has been a progression of pressure against pentachlorophenol, followed by arsenic, chromium, and recently copper. Tin and some organic biocides have also been swept up in these changes. Some of the concerns are toxicological while others are ecotoxicologically driven. From these pressures, renewed interest in wood modification processes has grown. While some of the research is focused on traditional modification methods such as acetylation, several groups in Europe are investigating the use of heating processes to provide protection from decay and to allow stabilization of the wood in service. While details of the processes tend to be proprietary, the commonalities appear to be inducing a high temperature atmosphere in the absence, or at least a lowered concentration, of oxygen. The processes appear to allow wood stabilization and protection against some decay organisms. Questions remain concerning termite protection, hygroscopicity and potential for decay in service from tolerant organisms.

One factor that needs to be acknowledged is the influence of European research on the rest of the global wood preservation community. A region with only 20% of the world's preservation market is providing a higher proportion than this of the research papers annually, and these appear to be concentrated in the test methodology and environmental aspects of research. In Europe, perhaps because of the thrust to homologate standards on that continent over the last decade, there is a well-established communication network that provides a framework for developing consensus approaches. Because of this, the European influence is disproportionately large, in part because of the lack of concerted research approaches in the rest of the world. Coupled with the likely influence of the European Biocides Directive on active product availability in the coming years, it seems likely that product initiatives that evolve in Europe are quite likely, for better or worse, to spread more rapidly around the world in wood preservation than has been the case in the past. One manifestation of this is a trend towards decreasing expectations of treated product longevity as an outcome of the harmonized European testing/approval philosophy and a lowering of performance expectations to meet the reality of this process. This concept, accidentally or wittingly established, is not necessarily bad, and can be considered to provide treatments that are more appropriate for intended end-use. It is likely that this will spread as the perception of adequate performance is equated with environmental desirability in terms of product life cycle analyses.

Such trends are fueling other research related to the environmental aspects of wood preservation. Among these are risk assessments of biocides, methodologies for risk assessment, leaching of preservatives and fate in the environment, extraction of chemicals from treated wood removed from service or degradation of removed treated wood to a manageable waste. Other such lines of research include the reuse of lumber through recycling and other options. One spin-off from the research on the disposal of existing treated wood is that early consideration into ultimate disposal of treated lumber is increasingly influencing the development of new preservative systems. However, especially in the U.S. where CCA treated wood dominates and will continue to dominate disposed treated material for many years to come, it appears likely that disposal methods for new preservative treatments that are compatible with disposal methods for CCA-treated wood, will be adequate, and necessary, for the foreseeable future

Fixation of chromated preservatives, especially CCA, continues to be of interest, particularly in Canada, although actual research in this area appears to be declining as commercial operations become accepted practice in some regions. On the other hand, fixation mechanisms for amine copper preservative systems and how to influence these in order to provide immobilized copper components in such systems is now under intensive scrutiny.

2.5 Preservatives

The research into "copper" preservatives over the last couple of decades has seen the commercialization of a series of alkaline copper preservatives which are based on copper as the primary biocide solubilized as an aqueous amine or ammoniacal complex, in combination with co-biocides to provide protection against copper-tolerant fungi and against termites. The products are derived from ammoniacal copper arsenate (ACA), developed in the 1930s, and updated as ACZA in the early 1980s. Examples of these products are ACQ (alkaline copper quat), Wolman CX (copper HDO), copper citrate, copper azole, and CDDC (copper dimethyldithiocarbamate). With the exception of CDDC the products are similar in providing copper plus another soluble component to enhance the activity of the copper complex. CDDC sought to form an insoluble copper dimethyldithiocarbamate complex in wood through precipitation from a two component treatment system. Such products have found good growth markets in Europe and Japan, although to date only ACQ has been a commercial success in the United States. Considerable research continues with the copper based preservatives. Extending their growth into the future will depend on enhancing copper fixation and complexation mechanisms. Recent research has showed that the addition of water repellent additives to the treatment solutions can significantly enhance the weathering performance and other attributes of these products.

Another area of significant research activity is the use of borates in Northern Hemisphere wood preservation applications. Borates have been used commercially in wood preservation in Australasia for upwards of 50 years, for protecting wood products from Lytus (Australia) and Anobiids (New Zealand). While the use of borates in New Zealand has declined recently with that market moving towards dry framing, research and commercial application in the U.S. has grown. Applications include framing and sill-plate lumber, and in some jurisdictions borates are considered to be suitable for protection from Formosan termites. Research is on-going into the suitability of borate treatments for exterior applications, although little positive data is available to support broad application in leaching environments. Research into novel organic boron complexes as wood preservatives continues with a view to developing non-leachable complexes that will provide biocidal activity through the borate present in the complex, while progress continues with the vapor boron treatment developments. Undoubtedly, borates offer unique opportunities to treat intractable wood species either by diffusion or through vapor phase treatments. The research challenges being addressed include leachability and performance questions in regards to some organisms. Also, in common with most biocides used today in wood preservation, borates are being subjected to similar negative regulatory restrictions in some countries.

Such negative regulatory pressures are increasingly driving parts of the European preservative industry towards the use of organic preservatives, especially in H3 applications. While the use of organic solvent-based systems has a long history in Europe, VOC issues are mandating a future in water-borne emulsion systems. Undoubtedly, widespread developments in this area will be dependent on success in providing water repellent emulsion systems compatible with the organic biocides, and in achieving penetration into species such as Scots pine. A further consideration will be the cost/performance profile. Undoubtedly, the lowering of performance expectations already seen over the last decade with the widespread use of copper-based preservatives will be taken another step lower with the introduction of water-borne organic preservatives into the marketplace. This dubious downhill slide does not augur well for the long-term future of treated wood in Europe. Beyond that, perhaps the greatest challenge from a North American perspective is the problem of wood surface degradation that occurs with non-metallic preservative treatments in the type of exposures encountered on this continent. Furthermore, little research has been carried out on failure mechanisms for organic preservatives, even in above ground applications, while the practical use of such materials in ground contact, other than in oil-borne carriers, remains a lofty goal.

2.6 Innovative Approaches

Beyond biocides, wood modification remains an academic research favorite in the US, Europe and Japan. It is an alluring concept, but one where cost effectiveness remains dubious. Undoubtedly, the greatest potential for chemical modification systems is in the protection of wood composites, but even here further development is needed. The recent moves towards the application of the heat treatment concepts in Europe appear promising for lumber, but challenges remain in regards to protection from insect attack, potential of tolerant fungal degradation, and the effects of moisture ingress even if the wood structure is stable. In all such systems, innovative approaches to quality control of the treated wood product will be needed for quality assurance.

One area of wood preservation research and development that has seen significant strides over the last decade, both in terms of research and commercial usage, is the field of water-based emulsion water repellent technology. This rather old concept is finally seeing significant market acceptance in the US and the long-term performance enhancements to be gained from such technology are only now being confirmed. Besides provided enhance weathering appearance and similar attributes, water repellents can provide significant improvements in lowering leaching and improving performance of a range of wood preservative components. Clearly, in a period of pressure to lower chemical loads in the environment, keeping wood dry, or at least drier, offers a significant step forward in reducing the need for biocidal protection in service.

The most fundamental research in the arena of wood treatments is focused on super-critical fluid treatments and vapor boron treatment. The vapor boron research offers potential particularly in the treatment of composite products, and perhaps in species such as SPF for protection from insect attack. Questions remain on registration issues and costs, the handling of the methanol by-product during or after treatment, and retention requirements. Several groups are known to be working with super-critical fluid treatments. While SFT offers greater versatility of biocide choice than is the case with VBT, serious question remain on the practicality and cost of commercial scale operations, performance in service and the inability of SFT, at least at this time, to protect wood products from water ingress in service. More practical aspects of treatments research include the fixation studies and analytical research described elsewhere, and in the advances in emulsion treatments technology over the last ten years. It is apparent that with the likelihood of increasing reliance on organic biocides in the years to come, emulsion preservatives and wood stabilizers will become the norm in our industry in the foreseeable future. The evolving knowledge in this area will provide the foundation for this technology.

2.7 Test methodology developments

One research area in wood preservation that continues to flourish is test methodology. While the 1980s saw a flourish of activity in the development and use of terrestrial microcosms (fungus cellars, facility for accelerated biodeterioration, soil beds and the like) for testing wood preservative treatments in natural soil in ground contact, research during the last decade has focused more on test methods for simulating above ground applications. This is a natural outcome of the predominance of above ground applications for treated wood in Europe, Japan and North America. New assessment field test methods have been standardized for decay hazards above ground, and some progress is being made with various termite tests simulating termite hazards in wood above ground. As part of an impetus to provide appropriate chemical retentions for geographically regional decay hazards, interest in climate indices to predict relative above ground decay hazards has been rekindled and research is on-going to further refine the tools available. Much other research is proceeding with methodologies to study fixation and depletion of preservatives in service, as well as measurement systems to more easily quantify physical weathering properties of wood products during aging.

Wood preservation research is often hindered by the variability in the base substrate, namely, wood. This variability mandates considerable replication of samples in almost any test involving solid wood as substrate. However, modern technology has been applied to wood preservation research to provide at least a modicum of relief from the tedium. These tools for tedious work include printable bar-code systems that have eliminated the need for laboratory numbering and writing, hand-held water-proof bar code reading data loggers that allow field testing to proceed in all weather conditions with less repetitive errors, digital voice recorders with voice recognition software that can allow verbal recording of data which is then directly downloadable into electronic file formats, rapid down-load of stored or recorded data to files which can be automatically processed electronically, and also the use of Intranets to provide smoother communication between scientists and staff, and to other parts of organizations. At a more prosaic level, the now-widespread use of email and other forms of electronic communication allow scientists in different geographic regions and organizations to share concepts, plans, and data rapidly and at little cost. Clearly, this could and should be used to the optimum for a relatively small focused research field such as wood preservation.

One practical problem in wood preservation research field is that the long times necessary to achieve meaningful results in many field sites make field testing an unattractive option for universities. Thus in Europe, for instance, research at many institutions focuses on laboratory tests of perhaps questionable predictive value because this allows students to complete their projects in a timely manner. This in turn has given rise to the laboratory test-only mentality now seen in the European approach to wood preservation standardization (it should be noted that the Nordic countries remain a bastion of belief in field performance, along with one or two other islands of sanity). In contrast, graduate student research has constituted a smaller portion of the intellectual property development outside of Europe. Institutions such as USDA Forest Products Laboratory, Forintek (and its governmental predecessors), FRI (now Forest Research), CSIRO, FRIM, QDF, various Japan institutes, and CSIR have over the years played a proportionately much greater role in wood protection research. For this reason, there has been a much greater emphasis on field research of concepts in order to determine whether developments actually can be expected to perform in service.

This may change as privatization consumes the government laboratories. Canada was the first to move in this direction some 20 years ago with New Zealand following earlier this decade. The recent drastic staff reductions at CSIRO in Australia portend further moves in this direction. It is inherently more difficult for a privatized institute to maintain long term field tests, given the differences in fiscal requirements, although Forintek and, so far, the NZ Forest Research, have been able to continue most of the existing programs in this area. Clearly, the need to satisfy most sponsors' short term funding horizons will make this increasingly difficult. However, it should be noted that Mississippi State University has been able to maintain large field tests although the future for these may be clouded should funding priorities or personnel change. At Oregon State University, the field test programs are maintained in part through on-going multi-sponsor cooperatives, which offer a more stable form of funding than is usually the case with single sponsors.

2.8 Funding sources

While as researchers we sometimes view our world as above the commercial fray, the reality is that funding issues are having a major impact on the type and range of research carried out in wood protection. For the non-tenured professor, it's publish or perish. For researchers in quasi-government laboratories and university research institutes, if you don't bring in direct research money you're in jeopardy. For researchers in industry, one's value is likely to be measured through one's impact on the organization's bottom line. One difficulty we face is that these days forest products research is viewed as low tech and part of the past - not as a compelling essential for the future. Thus funding prospects are lower. In the U.S., political pressure has allowed continued government funding to flow into selected forest products research laboratories during the last decade, but continued pressure to view national forests as parks rather than tree farms will surely take its toll. One area where funding continues to flow is in industry-based proprietary research and testing projects in wood protection.

Unfortunately, such funding is often low, short-term and difficult to publish. It would seem that research cooperatives offer a significantly better vehicle for funding long term research in this field. Essentially, industry-funded research cooperatives allow the spreading of risk and reward as well as providing for more stable funding on combined fundamental and applied research projects. Of course, companies have to be prepared to accept that the results of the research will be available to all members of the cooperative. Having said that, research developed by the members themselves from fundamental study with the cooperative can still provide proprietary gains. Cooperatives can provide a vehicle for open advancement of wood preservation technology and should be considered as a model in designing research projects. Examples of recent or on-going cooperatives include the BRE (UK) project on millwork protection, and the on-going Oregon State University cooperatives on Pole Performance and Maintenance, and on Super-critical fluid treatment technology.

3. Conclusions

Global research in wood preservation is characterized by a strong research community with excellent links, but fractious approaches. Research in wood products, including the wood preservation sector, is viewed as somewhat passé by scientific funding community making academic commitments to long term fundamental research programs difficult. The availability of pan-European funding has made for greater commonality of approach in that region for wood preservation research in recent years, but outside of Europe research tends to be fragmented and opportunistic. The wood preservation research community continues to work on a wide variety of research topics, and has adapted to the use of high tech tools to ease the tedium of the science caused by the inherent variability in both the substrate, and the capriciousness of the hazards encountered. There have been a number of successful examples of research consortia in wood preservation over the last twenty years. Further development of this concept may be of value in satisfying the needs of academia and industry to advance the science of wood protection, and to provide longer term stable funding to allow such developments to reach fruition.

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