WOOD PRESERVATION TO THE YEAR 2000

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INTRODUCTION

Wood preservation in North America has grown rapidly in recent years primarily through the increasing use of treated wood products in construction while the use of treated wood products in the industrial sectors has remained steady (1). The predominant preservatives used today, namely creosote, pentachlorophenol, chromated copper arsenate, and, the lower volume product ammoniacal copper arsenate and its derivative ammoniacal copper zinc arsenate, were all developed over fifty years ago. Each of these products has given excellent performance in specific areas of application and the continued growth of the industry is assured because of the positive role wood preservatives play in the conservation of our timberlands.

The increasing environmental pressures being brought to bear on many aspects of the production and use of the current preservatives are likely to have a significant impact on the shape of the North American preservation industry over the next decade. This paper attempts to identify some of these factors, the difficulties encountered in developing alternative approaches, and discusses some approaches which may provide the continuing growth that will carry the industry into the next century.

DISCUSSION

CURRENT TRENDS

The major wood preservatives currently used in North America, creosote, pentachlorophenol, chromated copper arsenate and ammoniacal copper arsenate were developed many years ago. The two oil treatments initially dominated the market through the treatment of industrial products such as crossties and poles. However, the rapid growth of the industry since the mid-1970's has been almost exclusively in the increased use of water-borne treatments in commercial and domestic construction and remodelling. These trends

should continue through the next decade and are likely to accelerate in the event that upward pressure on oil prices returns and as safety considerations dictate a move away from solvent treatments of millwork products.

The wood preserving industry is coming under increasing pressure regarding its use of toxic biocides. These pressures relate not only to the issue of possible acute and chronic toxicity to mammalian and other species but more importantly to the effects of the preservatives on the environment. Issues such as disposal of treated wood products at the end of their functional life, environmental cleanup of defunct and existing facilities, and registration and local ordinance are becoming of increasing concern across the industry.

While the industry has an excellent record in most aspects relating to these environmental concerns, it has been less than adequate in explaining the value of wood preservation as a means of dramatically slowing forest harvest rates and ensuring the retention of native forests in perpetuity. These are environmental concerns of major importance where wood preservation plays a very positive role in forest conservation.

Various groups in the area of wood preservation realize that while the continued use of the existing preservatives poses few hazards to humans or the environment, the need to develop alternative treatments is essential for the industry to continue to grow without undue restrictions on use and operational practices. Unfortunately, unlike agricultural crops, wood products in service are subject to a multitude of biodeteriogens over very long service lives. While the development of agrochemicals in recent years has required such biocides to be organism specific, rapidly biodegradable and non-soluble (2), the corresponding profile for wood preservatives still requires that they be broad spectrum, persistent in wood in service, and soluble in suitable carriers. Furthermore, the relatively small size of the wood preservative markets makes research into the synthesis of novel biocides for this specific application a not-too-attractive proposition.

Nevertheless, research is on-going and in order to achieve success without long term testing of treatments in service situation a variety of methodologies are being used.

METHODOLOGY DEVELOPMENTS

In general comprehensive preservative development programs must combine biological testing in order to establish the efficacy of treatments against a multiplicity of organisms with chemical studies aimed at providing information on the longevity or rate of change of the preservatives when exposed to hazards which could be expected in service conditions (3). In several countries approval protocols have been set up but in general these are guidelines which attempt to provide guidance in the development and testing of new preservative treatments (4). The complexity of preservative development programs, coupled with the reliance on field testing under a wide range of climatic conditions mitigate against the use of rigid protocols which could prevent the introduction of desirable new products in a timely fashion.

In recent years there has been a surge in interest in the use of accelerated testing of preservatives under unsterile conditions of high temperature and humidity in chambers variously described as fungus cellar, soil beds, accelerated field simulator, facility for accelerated biodeterioration, etc. Considerable effort is now being devoted to correlate the results from testing in these facilities with field tests (5-7). While these efforts are useful as guidelines, the results obtained must be treated as only part of an information base available for making decisions about the value of new preservative formulations. A "standardized" fungus cellar test will be of similar value as a "standardized" field test where comparisons within a test and site are highly valuable, but comparisons between sites - and facilities - reflect only overall trends in the rate of biodegradation of wood products whether treated or untreated.

Nevertheless, the trends towards testing under "natural" conditions are a highly significant advance over previous practices which relied heavily on laboratory decay tests against pure cultures of Basidiomycetes fungi known to have resistance to either currently or previously used preservatives.

PRESERVATIVE DEVELOPMENTS

The chemicals under investigation as new preservatives can be broadly grouped as either organic or inorganic in nature but recent trends suggest that future products are likely to be either organo-metallic complexes or mixtures of organic and inorganic components. Among the inorganic chemicals under consideration are copper, boron, zinc, cadmium, molybdenum and the lanthanides, while the list of organics includes carboxylates, iodo-carbamates, isothiazolones, sulfones, benzothiazoles, alkylammoniums, triazoles, nitrosoamines, chlorothalonil, etc (8-20). The potential of these compounds and combinations thereof has been discussed or reviewed extensively elsewhere (10,21). In general the organic products offer advantages in efficacy and environmental acceptability but the more complex biocides

among them are relatively expensive and they are unlikely to find use in general wood preservative applications in the foreseeable future.

Oil-borne preservatives are widely used in the treatment of poles, crossties and other heavy duty industrial applications. These treatments have the advantages of allowing pre-treatment sterilization of the wood through extended steaming followed by immediate treatment of the heated substrate. Oil-borne preservatives also have advantages in aspects such as the corrosivity, surface hardness, fire after-glow, and physical weatherability of the treated commodity. Conversely, oil-borne preservative treatments are considered to be at a disadvantage with respect to surface cleanliness of the treated wood, migration of the oil to the surface and groundline region, environmental problems at treating facilities, and to cost fluctuations with oil prices.

Water-borne preservatives have found favor in human contact situations because they give a clean, cost effective treatment which is easily handled in modern treating facilities (1). Perceived disadvantages relate to the effects of currently used formulations on the physical properties of treated wood.

In order to overcome the disadvantages inherent in the oil- and water-borne preservatives, in recent years a number of developments have sought to combine the perceived advantages of each. We have seen various water-borne pentachlorophenol systems developed (22,23), water emulsified creosote(24,25), emulsified additives for chromated copper arsenate (26,27), ammoniacal chromated copper arsenate (28), and emulsified chromated copper arsenate (29). Undoubtedly developments with such crossover technologies will continue and advance, with the consequence that the wood protection industry will become more sophisticated and adept with the use of emulsified formulations throughout the next decade. Furthermore, as consumers become aware of the advantages of inclusive treatments which protect treated lumber from splitting and cracking during weathering in service as well as providing protection from decay and insect attack, such inclusive treatments will become the norm and will find widespread usage throughout the next decade.

Among the chemistries that at this time are considered to be environmentally acceptable for use as wood preservatives, copper continues to be - as it has for the last half century - the most cost effective biocide for this application. As such it will likely be the "anchor" of the next generation of preservatives. However, copper has three major drawbacks that must be overcome in order to utilizing it successfully in wood preservation. These are corrosivity to treating plant and fasteners in service, susceptibility to copper-tolerant fungi, and susceptibility to some insect species. While the last of these is relatively easy to achieve the former two drawbacks present significant technological difficulties.

The approach with corrosivity has been either to use ammoniacal or amine systems to make low corrosivity treating solutions or to use chromate as a passifier in an acidic medium. This latter approach is becoming more tenuous with the increasing environmental pressures on chromium while the currently used ammoniacal and amine systems could be improved in respect of corrosion of fasteners in service, surface appearance of treated wood, and preservative distribution gradients within the wood. Another approach under investigation is to use chelating agents in acidic systems in order to prevent plant corrosion, and the success of this approach is dependent on balancing competition between corrosivity, solubility and biocide availability factors relating to copper in solution (30).

Overcoming copper-tolerant fungi with environmentally acceptable biocides to give formulations which are cost competitive with chromated copper arsenate is a difficult task. Arsenates have proved to be both highly effective and inexpensive in controlling copper-tolerant fungi and to date no totally effective substitute has been developed (31). Borate is widely used in Europe in chromated copper borate formulations even though these formulations have been shown to be less effective than chromated copper arsenate and the borate is susceptible to rapid leaching in exposed service (32). However, as concern for the longevity of chromium and arsenic containing preservatives, and for that matter pentachlorophenol and creosote, increases, research into other biocides to control copper-tolerant fungi is also increasing. Among the materials under study are naphthenates, carboxylates, alkylammonium, nitrosoamines, complex borates, dinitrophenols, other metal ions, etc.

Undoubtedly, the success of research in overcoming copper tolerant fungi will depend in part on developing further understanding of the mechanisms of copper tolerance that certain fungi display. The current knowledge is based largely on studies with the Cu^{2+} ion, and the extent to which deactivation by mechanisms such as oxalate formation can occur with copper complexes or cupri-amines remains unknown (33,34). Empirical approaches to new preservative development have been successful in demonstrating potentially effective preservatives, but a greater understanding of fundamental mechanisms is required in order to amalgamate our knowledge base for the development of the next generation of preservatives.

Borate wood preservatives have been used throughout the world for many years and considerable research into their

application for export lumber protection was carried out in British Columbia during the 1970's (35,36). Except for early stake tests at the Forest Products Laboratory - which failed very prematurely - borates have remained seemingly hidden as preservatives in the U.S. until a recent surge of interest. The USDA laboratory in Gulfport has carried out an extensive series of tests over the last decade (37-39) demonstrating the value of borates in specific applications. Borates are very useful wood preservatives having the positive features of relatively low mammalian toxicity, broad spectrum fungicidal and insecticidal activity, water solubility and low cost (40). Against these positive attributes one large drawback remains to the widespread use of these chemicals and that is the as yet intractable problem of leachability. The recent interest in borate preservatives has sparked renewed research into fixation methods but no commercially viable method has been developed.

Borate preservatives remain in the category of "appropriate technology" for certain applications. An example of this is the use of fused borate rods to provide a highly concentrated remedial treatment preservative. Recent studies have demonstrated the value of fused borate rods in pole remediation, crossties, and various millwork and structural lumber applications (41-45).

PROCESS DEVELOPMENTS

While new preservatives will begin to penetrate certain markets early in the next decade, research into new treating processes could also have a significant impact on both the scope of preservative usage and eventually on the types of treatment used (1).

Treatment process research has been a somewhat dormant science for several decades but current studies on new incising, gaseous, diffusion, alternating pressure and pulsation processes could open up the markets for hard to treat lumber species such as exist in Canada (46-49). Other studies on the efficacy of envelope treatments may also lead to increased assurance and usage of such treatments (50).

A more radical approach to improved treatments currently in the early stages of development is that based on the use of super-critical fluids as a carrier for the active preservative. This technology could revolutionize wood treatments by allow the treatment of difficult to treat species such as Douglas fir and the spruces, and also provide wood products which are dry immediately after treatment with no yard drippage occurring. Solvents with potential for this application include carbon dioxide which displays super-critical properties at relatively low temperatures and pressures. In the super-critical region carriers display the solvating characteristics of a liquid and the penetration properties of a gas. Small alterations in the conditions can produce large changes in solvation ability. Like other radically different ideas, the use of super-critical fluids in wood treatment is unlikely to find extensive commercialization before the year 2000. Factors such as the effect of the treatment on wood structural properties, extraction of wood chemical components, effect of novel solvents and treatment methods on preservative performance, etc all must be taken into account. It is also likely that no existing preservative will be readily adaptable to super-critical treatment processes, and thus a new material will have to be developed or adapted in order for this process to be successful.

MILLWORK TREATMENTS

Millwork treatments have been a small but relatively important segment of the preservative market in North America since the 1930's. For many years pentachlorophenol was the fungicidal active of choice in the U.S., but during the last decade there has been a rapid change first to tri-butyltin oxide and more recently to iodopropynylbutyl-carbamate based formulations. While these rapid changes have taken place, it is somewhat curious that the Canadian industry remains wedded to organo-mercury based millwork formulations. Europe is also seeing changes in active fungicide though in the U.K. tributyltin compounds remain in vogue, if under increasing environmental pressure.

Regardless of changes in active fungicides and insecticides, the greatest change in millwork treatment likely during the next decade will be the use of water-based formulations as a substitute for light solvent treatments. Considerable pressures are pushing that that direction in Northern Europe and Scandanavia, and in certain situations water-based formulations are already being used by millwork manufacturers in the U.S. (51). Technical difficulties relating to drying time and grain-raising remain as obstacles to market acceptance (52), but it is likely that the application of micro-emulsion technology will provide a satisfactory solution to these problems in the next few years.

FIRE RETARDANTS

The wood protection industry has long viewed the fire retardant treatment sector as a potentially lucrative market for development. Unlike the preservative sector, however, fire retardant chemical manufacturers have yet to come to grips with the needs of the industry as a whole. The wood

fire retardant industry remains highly fragmented with each company producing an individual proprietary formulation. Quality criteria depend on end-product performance standards using accelerated testing procedures. Unfortunately, these structures have lead to an industry which is inward looking rather than providing a unified approach to competing against other materials. Available resources are expended on internal competition among the wood product fire retardant manufacturers and the market has not grown to its full potential.

In order for the fire retardant industry to grow, a new structure and comprehensive quality assurance scheme is needed. This should be based on providing retention levels of specific fire retardant active ingredients in the treated commodities through quantitative analysis of the treated product. Provision for the proprietary needs of the manufacturers could be incorporated through standards based on comprehensive performance protocols. This type of quality assurance scheme has provided consumer confidence in treated wood products and no doubt contributed to the rapid growth of the wood treating industry during the last two decades. Developing such a scheme for the fire retardant industry should lead to rapid growth in the market for wood product fire retardants as the end-users gain confidence in these products and specify them in preference to steel, concrete and synthetic polymer-based materials.

WOOD-BASED COMPOSITES PROTECTION

Composite wood-based products are growing rapidly and products such as oriented strand board are replacing "solid" wood materials such as plywood in various markets. In other areas research is directed towards the use of wood-polymer composites as replacements for polymer-based materials and this type of development augers well for the wood industry which has traditionally been very good at competing with itself but somewhat lacking in its approach to competitive materials not based on wood fiber.

For the continued growth of the composite industry the successful use of these products in exposed situations subject to weathering and fungal and insect attack will be necessary. Research into protection agents for composites has been on-going for many years with the most developed research and commercialization having taken place in Germany. A recent conference in Canada centered on developments in this area and highlighted several needs that must be met for the successful development of appropriate products and their marketing (53). Among these were:

- new protection agents
- dimensional stabilization agents
- fire retardants
- wood modification at low add-on
- appropriate treatment methods
- compatibility between treatments and adhesives
- test methodologies for performance prediction

The accelerating research resources currently being expending in this area should lead to the commercialization of such products during the next decade. This is likely to be an area of evolutionary product change and improvement for the foreseeable future, particularly if significant gains are made in the use of wood modification as a means to induce dimensional stability in the composites.

TRENDS

Among the trends likely to develop over the next decade are a movement towards greater homologation of standards. The driving force behind this will be the development of significant international trade in treated wood products. Current standards are generally incompatible but the changes taking place in Europe and Australasia will spread and eventually lead to mutually beneficial changes and greater uniformity of standards worldwide. It is conceivable that process standards will be dropped in favor of the performance criteria which are the norm in several countries, but this will be dependent on the development of realistic performance criteria for refractory species such as the spruces.

The growth of sub-tropical and temperate softwood plantations is likely to also lead to increasing use of anti-sapstain chemicals, though the use of improved spray technology in temperate countries may offset this trend.

The remedial treatments industry is likely to enjoy continued growth and this will be especially so if environmental pressures lead to a lowering of preservative performance standards. The development of new transmission technology by the utility industry could however have a very negative impact of the treated pole industry.

As new preservatives are developed there will initially be an increased diversity of treatments available. However, with time consolidation will occur though the industry may remain more specialized than it is today.

CONCLUSIONS

The next decade will see continued growth in the wood products protection industry with an increasing diversity of treatments and markets. Environmental pressures will continue to grow and this should induce a change in the technology base of the industry. New preservatives will find acceptance and the current trends towards providing protection from both biodeterioration and physical weathering will be continued with these new preservatives.

These changes should lead to increased research and development although the current precarious situation with respect to undergraduate and graduate training in wood protection could create severe shortages of skilled technologists. While the new products will arise from applied research, basic research in areas such as understanding of biodeterioration pathways, chemical fixation processes, the effect of moisture on preservative performance, novel wood modification methods and a greater understanding of penetration mechanisms and chemical interaction in wood will provide the knowledge base necessary for success in the applied sector.

In summary, wood products protection industry has many opportunities in which to continue to grow throughout the coming decade. Technology change is accelerating and increased resources must be devoted to both technology development and to education of the technologists who will be responsible for these changes. If we fail to educate the necessary personnel and to develop the new technologies the industry could be in a very vulnerable situation by the end of the decade.

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