A VISION FOR THE INDUSTRY – FUTURE PRESERVATIVE CHEMICALS

John N.R. Ruddick
Department of Wood Science, Forest Science Centre, University of British Columbia, 2424 Main Mall, Vancouver, B.C. V6T 1Z4

1. Introduction

Predicting the future is fraught with difficulty, if only because it requires one to foresee the unforeseen. The wood preserving industry on the one hand, seems to be booming with few visible problems. However, those close to the industry realise that this is not the case. There is increasing concern over the disposal of treated wood. This has potential to become a major problem since the amount of treated wood being used is still increasing. One positive aspect is that burning of creosote treated poles should not prove difficult and even the commercial incineration of pentachlorophenol treated wood is feasible in a high temperature incinerator. However, both poles and piles are in service for more than 40 or 50 years before they are removed. This is not the case with the chromated copper arsenate (CCA) treated sawn wood used for decking or fencing. There, appearance dominates the acceptance of the product, and recent surveys have suggested that decks may be replaced in less than 20 years, simply because of excessive weathering, discolouration, or checking. The disposal of these large volumes of lightly treated wood will pose a challenge or an opportunity, depending on your outlook!!!

The industry is also facing the impact of increased globalization, where practices in one country affect those in its neighbours. This is clearly seen in Scandinavia where the elimination of CCA-treated wood for above ground use in Sweden has been taken one step further in Denmark, where the complete elimination of CCA has been proposed. Indeed, the number of countries that are considering either eliminating or reducing the use of CCA is increasing. It now includes Austria, Denmark, Germany, Holland, Japan, Italy, Sweden and Switzerland. At the present time there are no indications of legislation requiring reduced use in Canada. The recent review completed by Environment Canada, the Strategic Options Process (SOP) made no recommendations that limited the use of any of the major preservatives. The principal focus was on the Design and Operation of Treating Plants, with a review of the current compliance, the most visible impact. It is unlikely therefore that this process will have any significant impact on changing the way the industry operates, since a previous survey found a high compliance with the Guidelines in terms of worker exposure, and reasonably high compliance with respect to the plant design. The main problem with the plants that do not comply is that they are generally older plants, where the necessary changes are cost prohibitive. It remains to be seen how Environment Canada will deal with this lack of compliance.

In addition, the globalization of pesticide registration is now becoming more of a reality. More international attention is being focused on the Biocides Directive, which was discussed first within Europe, and more recently by the Organisation for Economic and Community Development (OECD) at their meeting hosted by the European Chemicals

Bureau (ECB). Here the focus was on developing a harmonized approach to wood preservative approval and use. Further evidence of globalization can also be seen from the activities of the International Standards Organization (ISO) actions, in developing an international standard specifying preservative use in terms of wood durability. So it is clear that potential for significant change certainly exists. The question is, whether it will become a reality.

Before embarking on a rapid review of possible changes in the chemicals that will be used into the foreseeable future by the North American industry, a number of questions posed by the Symposium organizers must first be answered.

2. The future of the Canadian Wood Preserving Industry

2.1. What was the greatest development in wood preservation in the 20th century?

Without a doubt one of the most important chemical developments was the evolution of the CCA formulation in the 1930's by Kamesam and Falk. This preservative is not only extremely cost effective, but contains many benefits not considered at the time of its development, such as being well fixed, and resistant to weathering.

However, if one looks at the factor that has had the greatest impact on the industry, then *the* greatest development becomes clear. It was the embracing of wood preservation by the general public in the 1970's and 1980's. Without this development the industry would be struggling to survive today, with all of the traditional markets under pressure due to lack of growth and competition from alternative materials. If CCA had not been developed, then an alternative treatment would have emerged to satisfy this market need. Indeed it is the concern over how best to serve this market which provides one of the biggest challenges in the immediate future.

2.2 What will be the international trends and will North America follow them?

As discussed in the introduction, understanding the global trends in wood preservation will be the key to Canadian industrial preservation surviving in a sound economic state. It is clear from recent events in biocide approval, standard development and environmental pressure, that the world is becoming much smaller. Environmental pressure groups are capable of organizing on an international level to affect changes that they perceive as vital for the well being of society. In addition, the wood preserving industry is now a mature industry. Consequently, major opportunities in other countries will increasingly result in more treated wood being exported. Examples of this are the shipment of borate treated wood, from British Columbia to the southern USA, Hawaii and Japan.

The question of whether Canada will follow the trends elsewhere is more difficult to predict. If major market opportunities emerge in the USA then companies will want to maximize their benefits by serving the local market also with the same treatment. In addition, there is a clear trend to using less chemical or even doing without chemical in Europe and Japan. (For example in Europe there are several heat treatments that have attracted attention.) These trends will clearly impact on Canadian practice. Indeed there is ample opportunity to reduce the amount of chemical used very significantly – an opportunity missed by the recent SOP process. Such lack of foresight will certainly haunt the industry in the future since the general public does not easily forgive such errors of judgment.

Evidence of the outside impact on treating practices in Canada is certainly already evident, with the recent proposed adoption of the Use Category System adopted first in Europe, Australasia, and Japan. Canada's treating industry is already on a path of radical change that will take effect during the next five years.

2.3 Where will the industry be in 10 and 25 years?

This question is more difficult to answer. Change occurs slowly in the Canadian Wood Preserving industry. During the next five years I do not see much change in terms of the chemicals or processes. I do see some consolidation as smaller companies are bought due to a reduction of local markets and an increasing reliance on export opportunities to the USA. Also I see the emergence of more "light" preservative treatments for above ground use, which will also serve "niche" markets.

In ten years time I believe that the widespread use of preservatives without chromium or arsenic for above ground structures, will become a reality. CCA will be phased out for the Do-It-Yourself market. The main drivers for this will be, a) public concern over the use of the chemicals leading to contamination of land and water, but more significantly b) concern over suitable recycling/disposal methods. The emergence of totally organic preservatives for above ground use will become established during the next ten years. After 25 years, I do not see wood preservative chemicals being used. Wood modification will have become commonplace. Indeed the emergence of composite material made from wood, cement, plastic etc will begin to emerge even during the next decade, as Society attempts to recycle all materials effectively.

Perhaps one of the main developing markets will be in the use of waste/recycled treated and untreated wood. We have already seen the new technologies for controlled pyrolysis of wood to produce bio-oils. Increasingly the focus will shift from how to "get rid of this waste material", to a new vision, of how to "best utilize this valuable resource". When this shift occurs, new industrial opportunities for wood utilization will be born.

2.4 What part will the three major wood preservatives creosote, pentachlorophenol and CCA play?

Creosote will be gradually phased out during the next ten years. As the reserves of oil diminish, attention will turn to coal tar derivatives to service the chemical industry. This will render the supply of creosote unreliable. Only the utility pole industry remains a major user of pentachlorophenol and the volume used continues to diminish. Increased pressure on the pole industry over the disposal of treated wood, and the loss to the environment of oil and chemical from poles in service, will finally cause the demise of this preservative. Within the next ten years there will be proposals that CCA should be limited to protection of wood in structural end-uses.

Looking at the longer view, CCA will clearly be replaced within the next 25 years. Copper-amine wood preservatives will primarily replace it in the near term. However, for above ground products (decks, fences etc) it is likely that totally organic systems will become established, with easy disposal, and effectiveness in maintaining the appearance of a deck, being prime considerations.

2.4 What part will alternative products and composites play?

This question has already been answered in part by the proliferation of structural composites developed over the last 20 years. The emergence of wafer board for sheathing of buildings has seen the virtual demise of the plywood industry. Parallam and other strand products have now begun to make significant inroads into the traditional glulam markets. Other combinations of wafer board and veneer lumber for trusses show how the future of the building industry is going to develop. **This is an important observation, since there are no signs of industrial development that can "jump-start" major new market opportunities for wood preservation. The future well being of the wood preservation industry will depend largely on how well it is able to gain access to wood used in building construction, including landscaping and outdoor use.** Clearly then, with composite products destined to become the major wood based products used in buildings, if preservation is to access those markets it must adapt to serve the new products. We can expect to see new technologies for treatment of composites, including vapour phase treatments (such as that used by boron esters), super critical fluid treatments, and the use of preservatives added to the glue to distribute during composite manufacture.

Innovation will always be the watchword for market development. For example the combination of treated wood waste with untreated wood to make a product able to be used above ground in a low decay hazard, will provide one opportunity. It is clear that even erratic treatments can provide useful service provided the decay hazard is low or moderate.

However, perhaps the greatest impact will come from the combination of waste materials that can complement each other. In such composites, the weakness of wood becomes its stength, as its role in mixed composites may be to provide biodegradability, while the other materials can assist in reducing the decay hazard.

2.5 *What are the biggest challenges in the next 10 and 25 years?*

In summary, disposal of waste will become one of the most pressing needs. While there are technical difficulties of sorting wood treated with different preservatives, finishes, or even just soiled from ground contact, these are relatively easy to solve. Tracer elements can be added to wood preservatives if required. However, rapid computer controlled analytical equipment that can operate in real time are a more likely solution. They exist in many other industries for monitoring effluent and other waste streams. Even the trivial but nuisance of metal fasteners in wood which must be located and removed before processing, is a relatively minor problem and can be easily solved. The collection of wood waste is interestingly more easily solved for the residential market, where the material is concentrated around communities so that a "Wood Blue Box" concept is realizable. However, for commercial uses, such as poles, ties etc, the collection of the treated wood may continue to pose a problem since transportation to suitable disposal/wood treatment sites will be expensive.

However, equally important will be the adoption of the concept of the recycled wood as a valuable resource that can serve many market segments. A whole new industry will develop that will serve the recycling of all materials not just wood. However, wood will become one of the prime targets for this new industry because it will be extremely versatile, being used in solid, flake, strand, powder or sheet form. Even when converted into oil by pyrolysis, the products extend the usefulness of wood waste. If this is achieved then the transportation and other costs may be recovered and a profit gained on the whole operation.

The environmental focus will continue to be on contamination of land, air and water, with water becoming increasingly important. Thus emissions from wood being treated, or treated wood in storage in particular will become even more restricted. Losses of copper and arsenic from treated wood around the home will become an issue, perhaps more an emotional issue than one that can be demonstrated from scientific observation. Nevertheless the industry has seen how such issues can cause major changes in user acceptance of products. Consequently, the lack of public trust in such preservatives will accelerate the move away from CCA first to amine copper preservatives, and later to organic preservatives. Within 25 five years, modified wood will be the main route for enhancing wood durability.

Quality and uniformity of treatment will become a major concern. Both the Canadian Standards Association and the America Wood Preservers Association, as the principal standard writing organizations for preservative treated wood, will be under increasing pressure, as the markets will be dominated by consumers and users who are not willing to spend time and commit resources to develop appropriate standards and inspection protocols. This is already happening where the majority of wood produced now does not conform to any standard and the purchaser does not consider the need for proof of a minimum standard, as necessary.

As the industry becomes more fragmented, with more chemicals being used in niche markets, the impact of the major chemical suppliers could become marginal. Such a change in the way the industry is structured would not be beneficial, in that the chemical suppliers have provided important technical support in ensuring plant compliance with regulatory demands, as well as encouraging treaters to upgrade equipment and offer warranty on products. This can be avoided if the major suppliers, market alternative preservatives for different uses. However, the potential for conflict between different treaters supplying into the same market using two different preservatives from the same supplier, is very real.

Globalisation will result in changes to the way in which treated wood will be described in standards. The Use Category System (UCS) will be user friendly but it will require the treaters to become more involved in the standards setting process. They will also experience a learning curve regarding the requirements of the UCS. The implementation of the SOP recommendations will also provide some challenges to some plants as they strive to impose the modern requirements on older plants. The impact of the Biocides Directive together with the global approach to wood preservative approval and regulation, will no doubt increase the complexity of the plant operation, resulting in higher operational costs.

Finally, the wood preservation industry will become more technical and varied, as the advanced composite products, preservatives and processes are introduced. This will require higher qualified persons working in this sector. It will be necessary for the industry to work with universities and colleges, to develop programs designed to encourage bright young persons to invest their careers in this sector. Without this, it is difficult to see how the industry can successfully overcome the anticipated technical challenges during the next 25 years, and emerge in a position of strength and technical excellence.

Visioning for Wood Preservatives.

Wood preservation is not know for adapting to change quickly. Creopsote was developed in the mid 19th century and remains a prime preservative today for piles, timbers, and – for its initial use in Canada – railway ties. Although some metal preservatives were considered at the beginning of the 1900's none gained acceptance in Canada and it was 100 uears from the introduction of creosote in Europe before pentachlorophenol gained widespread acceptance for commercial use in Canada for poles. About twenty years later waterborne preservatives CCA and ACA were adopted and began to be used for poles and sawnwood. However, in the twenty years the demographics of the wood preservation inducstry in Canada has changed dramatically, such that the newer preservatives dominate the market development (Figure 1). CCA now accounts for almost 85 percent of treated sawn wood in Canada. In addition, over ten new preservatives have been developed around the world during the past decade. Unfortunately, none has gained widespread acceptance in North America. The reason is not The reason is not hard to fathom. CCA is a very cost effective preservative. Any alernative will be more expensive

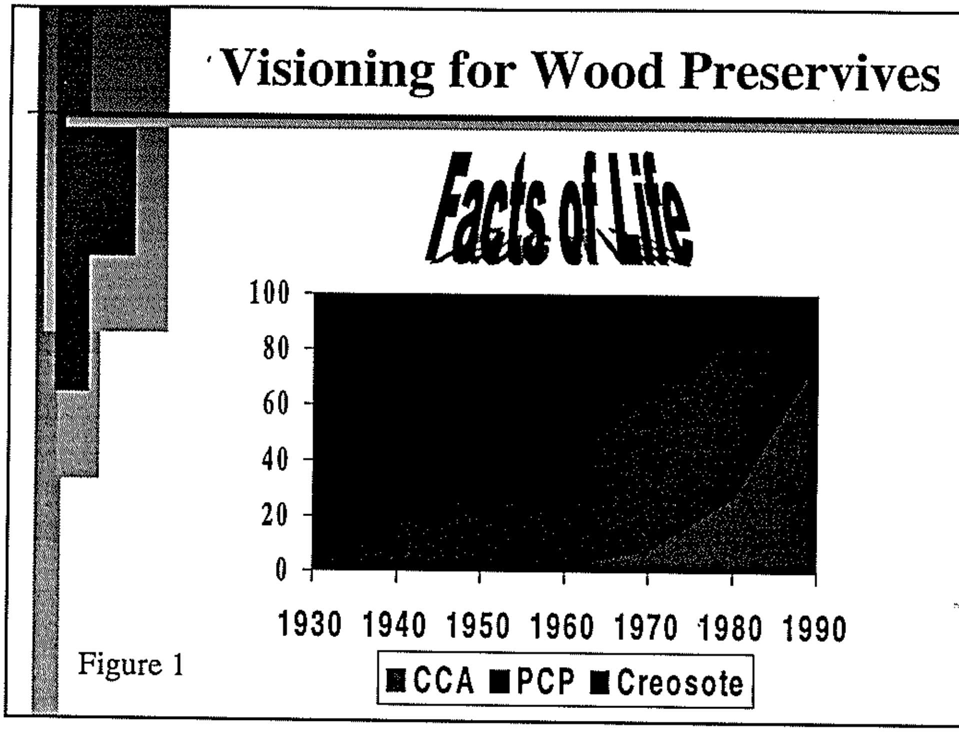


Figure 1

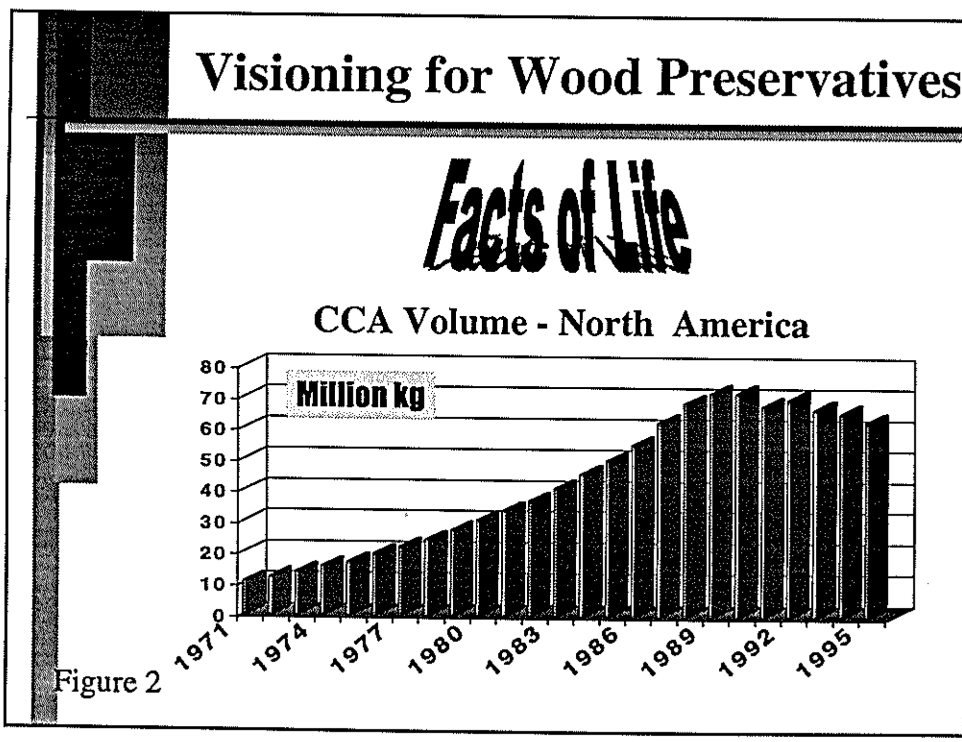


Figure 2

and must match the high degree of fixation achieved by CCA. But there are signs of factors which can induce change. There are indications that the CCA market has plateaued and begun to decline (Figure 2). Some of this may be due to reduced building starts, but equally importantly some builders are now looking at alternative treatments and even materials (recycled plastic lumber) to address environmental pressures.

What are the factors driving change. These include the known carcenogenic effects of chromium(VI) and arsenic. It is not difficult to understand the reluctance of some home owners to build decks out of wood containing known cancer causing components. There is increasing evidence that even for CCA, soil and water contamination are being recorded. Much of this has been attributed to placing treated wood in service before the chemical fixation reaction has been completed. However, even CCA-treated wood in which the fixation reaction has gone to completion can lose chemical when placed in certain soil environments (e.g. a soil which is high in humic or fulvic acids, or which is a glaysol loam that is waterlogged periodically). "Service life needs" is another factor which must be considered. Appearance is extremely important for wood used around homes. Decks are replaced, not because the rot, but because they no longer appeal, due to colour changes, checking and warping, splintering, etc. A recent survey found that many decks will have a service life of less than 20 years. With a service life of 20 years or less, many other chemicals become candidates to supply product into this market. And since it dominates the market (Figures 3 and 4) the potential for significant production is realizable. Thus preservatives which, can minimize weatherability and checking more effectively than CCA, but which pose less of a disposal problem, have significant potential to become practical alternatives. With organic preservative, formulation to include additives to address these issues is relatively easy, compared to modifying CCA.

But in what directions will wood preservative development head during the next decade (Figure 5). We have already seen some idea of the immediate concepts with the evolution of the amine-copper systems, where the copper-amine is complexed in wood (ACQ, copper-azole), or precipitated in wood (copper-HDO). For wood not exposed to moisture, borates have emerged as a prime candidate for this end use, primarily because of its low toxicity and ability to completely penetrate into unseasoned timber. When products are dry, for example as in composites) vapour phase borester treatments have been promoted as the answer for this product.

But already it is clear that organic wood preservatives having low mammalian toxicity and which allow the wood to be disposed by methods appropriate for untreated wood, will form the basis of the next generation of wood preservatives. The appeal of such preservatives can be enhanced through the formulation with additives which can reduce the wettability of decking or fencing, thereby reducing the decay hazard. We have already seen early examples of organic wood preservatives in:

- didecydimethylammonium chloride (DDAC) and other quaternary ammonium compounds such as betaine, which has been shown to be very effective against decay fungi but is less so against moulds, which can cause it to be degraded;

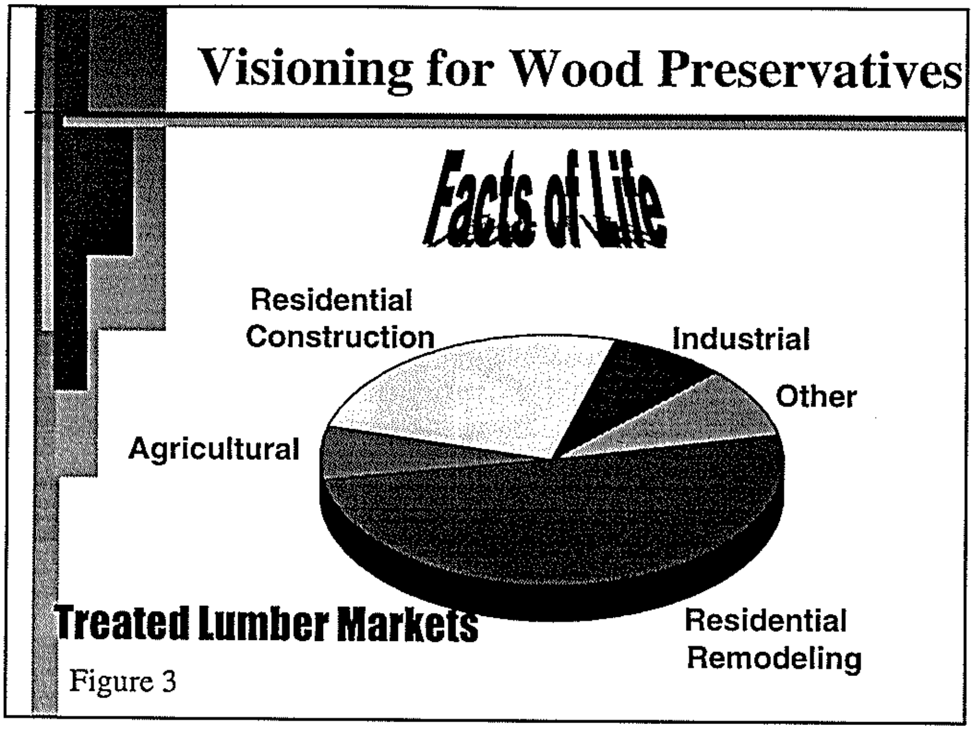


Figure 3

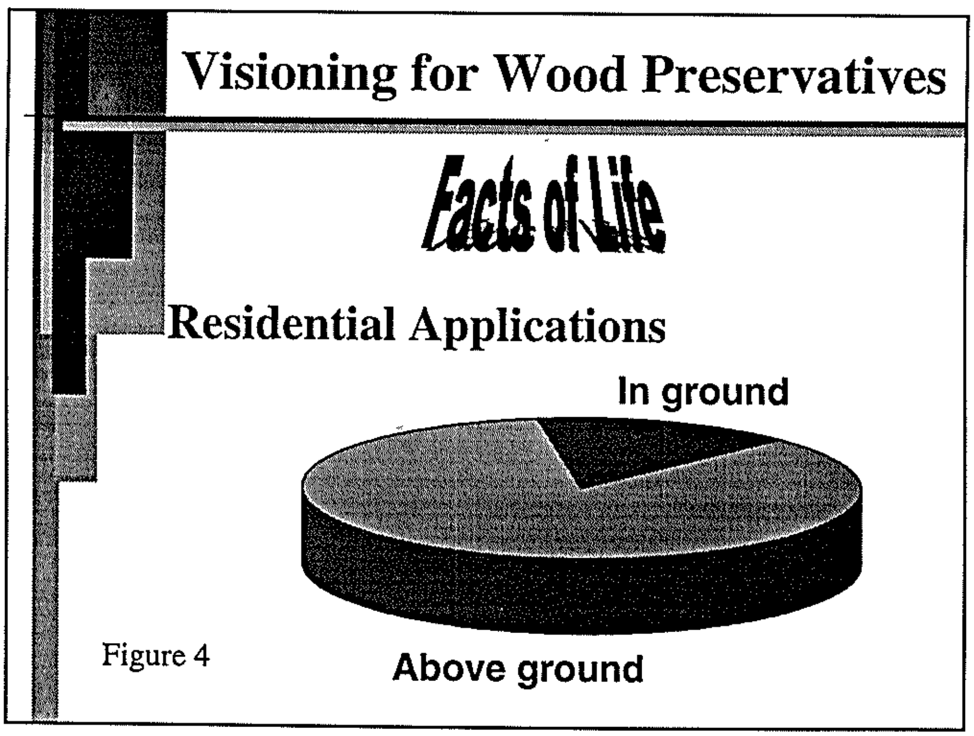
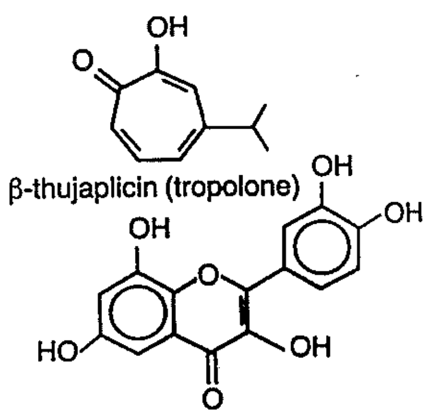


Figure 4

Visioning for Wood Preservatives

Figure 5

Visioning for Wood Preservatives



Quercetin (flavonoid)

Figure 6

- 3-iodo-2-propyl butyl carbamate, being widely promoted for the protection og millwork by non-pressure treatments;
- tebuconazole, propiconazole, hexaconazole, and other triazoles, some of which have already been used in amine copper based formulations;
- isothiazilinones;
- natural extractives such as terpenpoids (β-thujaplicin found in western red cedar) or flavanoids (taxifolin found in Douglas-fir) recovered from wood waste, eg bark and other sawmill waste. (Figure 6)

All current preservatives deplete at a measurable rate when the treated wood is exposed to liquid water. Even the newer copper amine preservatives suffer from this limitation. The use of co-biocides can assist in the insolubilisation of the copper and more effort will be made to use this strategy in the future. Biocidal chemicals that can, or could be, covalently bonded to the basic wood chemical structure in an essentially irreversible reaction would solve the question of leachability. But if taken to their extreme, would they work? To which wood component should they be bound and to what functionality? (Figure 7) These questions must be answered if this strategy is to be successful. However, work is already in progress to better understand how the copper preservatives are bound in wood. Structures of copper vanillin complexes which could mimic reactions in wood have been elucidated (Figure 8). Conventional, - Fourier Transformed Infra Red Spectroscopy (FTIR) and exotic (x-ray photoelectron spectroscopy (XPS) or electron spin resonance spectrometry) spectroscopic techniques have been employed to better understand which functional groups in wood are activated during preservation. In Figure 9, the ability of the amine solvent to irreversibly eliminate the carboxylic functionality in wood was demonstrated showing it can play an important role in wood modification. The same technique can also demonstrate the formation of copper-carboxylate complexes – Figure 9- during copper-amine treatment. XPS spectra can distinguish different forms of nitrogen, as demonstrated by the spectrum of amine copper nitrate treated wood (Figure 10). These and other studies need to focus on the reactions between preservatives and the different components that make up wood. Evidence to date suggests that most key reactions involve reactive protons on the glucuronic acid in hemicellulose or the phenolic protons in lignin. There is much scope for research here, with site specific reactions being one key to future wood preservative development. It is interesting to note that very little preservative is required to prevent decay. Certainly relatively few of the functional reaction sites require to be altered.

The logical extension to this research is wood modification, and I believe that it this direction that will result in the next truly new generation wood preservative process. Rather than a simple acetylation, where large volumes of reactant indiscriminately change hydroxyl groups, wood modification will target specific "functionalities" in wood to achieve enhanced durability, reduced weathering and dimensional stability, with small amounts of chemical. The emergence of composites as the main building timber in the future, will also provide new opportunities for wood preservation. Gue line additives will enable a new range of chemicals to be considered by the industry. However, even more advanced are combinations of materials where the wood and the co-host material each work in a synergistic way. The wood can add the biodegradability to the composite. The

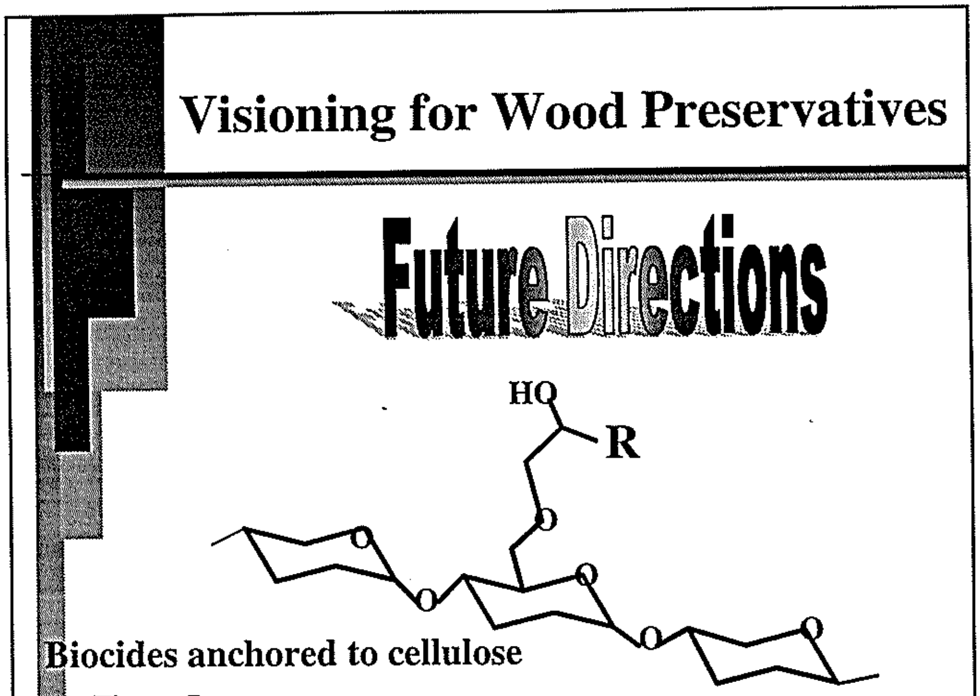


Figure 7

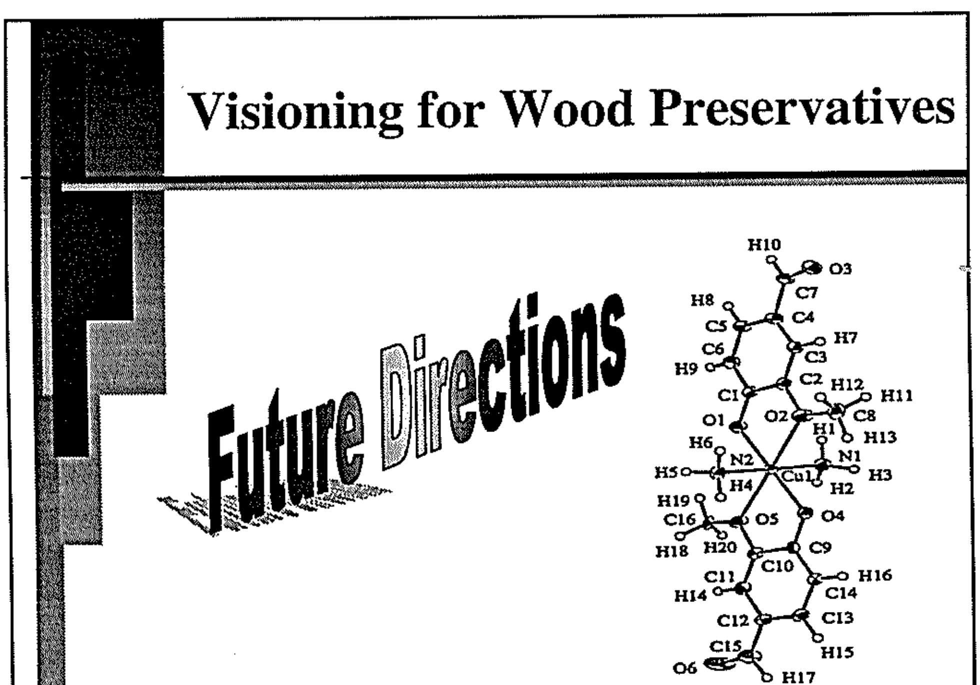


Figure 8

Visioning for Wood Preservatives

FTIR* spectra *of en and Cu-en treated wood

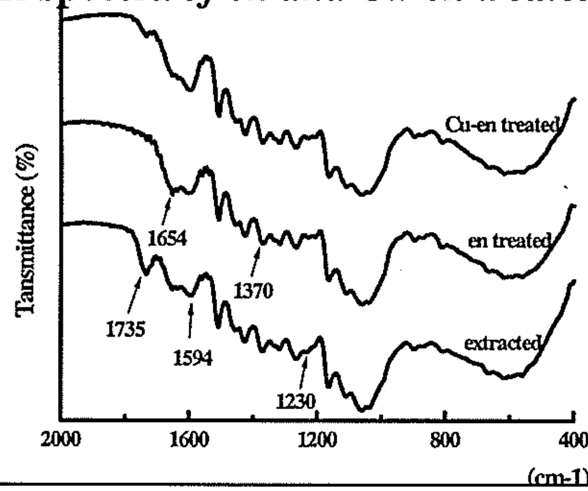


Figure 9

Visioning for Wood Preservatives

XPS N1s spectra of pure $Cu(en)_2(NO_3)_2$

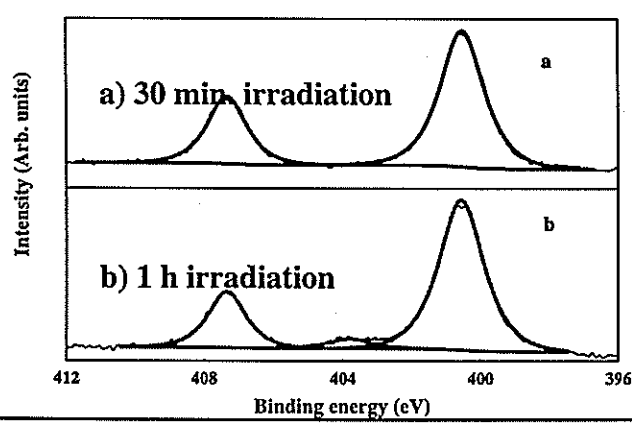


Figure 10

rate of biodegradability can be modified by either the choice of the co-host material, or through the treatment of the wood. This offers interesting possibilities for the future. Which chemicals best lend themselves to this product? What other properties can wood supply to the final product? Again more research is needed to develop this exciting market.

A novel approach to protecting wood is to bind biocides to wood components that would normally be attacked by fungi. Thus in doing so the fungus would release the biocide and then be killed. Such suicide fungicide research has been in progree for more than a decade. Alternatively, enzyme inhibitors can selectively disrupt the metabolic pathways of wood decay fungi (e.g. manganese peroxidase inhibition)

Product life will also become more important in the future. There is an interest in reducing the amount of chemical used to a minimum. With the prime markets being centered on residential products, most of which are used out of ground contact, then combinations of organic biocide with hydrophobic agents to reduce the wettability of the wood, - and hence reduce the decay hazard – must be considered to have good potential. Such an approach also meets the criterion that the new treatments must minimise the environmental impact of wood treatment, but at the same time it must consider the ease of recycling and reuse of the treated wood at the end of its first life cycle. These twin drivers will take the industry in the direction of more limited treatments. And the "Life Cycle" for wood products will continue to be competitive to all other building materials. A key to maintaining this is to minimise the environmenatal impact at all phases of production and use.

It is clear that in order to move in the direction of the future, the producers of treated wood and the users of their product, must listen to each other. But how do we get them to work together? What should be the role of each? How do we develop the understanding of our respective roles? But most importantly – Does the industry want to partner? Unless the wood preservative industry provides the products that the customer wants, the user will turn to other product suppliers that heed their input and develop products that respond to their needs. This is a challenge that the industry has never faced before – since this time the consumer is the general public. The same group that lobbies for reduced harvesting in old growth forests, and urges a ban on pesticide use on their neighbour's back lawn. But I do believe that the wood preserving industry can overcome all of the obstacles and emerge with exciting new directions for extending the life of wood and conserving our valuable, renewable, forest resource.