PROTECTION FROM BIODETERIORATION OF UNSEASONED CANADIAN SOFTWOOD LUMBER DURING STORAGE AND SHIPMENT

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INTRODUCTION

The Canadian softwood lumber production during 1980 was 19 billion board feet, from which 65 percent was exported. Considering some of these exports, about 76 percent was sent to the United States and five percent to the United Kingdom. From the total Canadian production, B.C. produced 12 billion board feet, of which 74 percent was exported for a total value of $2.5 billion (COFI, 1980).

The protection of this most valuable naturally renewable resource is of paramount importance, both to B.C. and to Canada. Recognition of its vulnerability to biodeterioration occurred at about the turn of the century, when it was recognized that freshly cut, unseasoned softwoods developed unsightly growths of mould and staining fungi of various colors. Some time later, the use of sodium carbonate and biocarbonate as a sapstain and mould preventive became popular in many lumber mills. Rapid air seasoning or kiln drying could have prevented these unwelcome biological growths, but such a procedure was not to be economical for the production of large volumes of export lumber. Today, with escalating energy costs, drying of lumber for export has become an even more unlikely solution to the mould and stain problems.

Early in the 1930's, several new chemicals based on chlorinated phenols made their appearance. Salts of both tetrachlorophenol (TCP) and pentachlorophenol (PCP) became popular, sometimes with the use of borax as a buffer, supposedly to improve the performance of the chlorinated phenol and improve the handling characteristics from the viewpoint of toxicity to the workers. The use of organomercury compounds as additives to chlorinated phenols also became popular at this time. At a later date this fungicide proved very effective in controlling brown mould (_Cephaloascus fragrans_ Han.). However, because of the environmental hazards associated with mercury, the use of this compound in B.C. was discontinued in the late 1960's.

Today in Western Canada the protection of unseasoned softwood lumber is almost exclusively dependent on the use of sodium TCP solutions. It is estimated that about 800 tonnes per year are used for this purpose (Jones, 1981). In Eastern Canada sodium PCP was more popular but lately a conversion to sodium TCP is occurring. A similar situation is occurring in the United States, probably resulting from the lower levels of hexachlorodibenzo-p-dioxin in sodium TCP compared to sodium PCP (Woolson _et al._, 1972).

Clearly, the export lumber industry in Canada depends on the use of chemical treatments to protect this product from source to its ultimate destination for which periods of up to two years could be involved (Cserjesi, 1980). These long shipment periods reflect the market, the more difficult current labor problems involved in the production of lumber, together with the evolution of very large lumber ships, which has necessitated the accumulation of larger volumes of lumber at the dock in preparation for loading. Also creating more hazardous biodeterioration problems has been the conversion of the industry from shipment of unpackaged random length lumber to packages of tightly strapped lumber. This latter method has severely restricted the drying of lumber during shipment, thereby creating conditions ideal for the development of mould, staining and decay fungi. It is estimated that should the current use of chlorinated phenols be terminated suddenly in Canada, then an economic loss due to downgrading of unseasoned softwoods could be in excess of $1 billion annually.

In this paper we will now consider the biological hazards threatening the Canadian export of unseasoned softwood lumber, current chemicals in use and their methods of application, quality control by the lumber industry and the economics of protection. Because by far the largest volume of export softwood lumber is produced from B.C., greatest emphasis will be given to B.C. conditions and production.

BIOLOGICAL HAZARDS

Mould and Staining Fungi

These fungi are not considered wood-destroying fungi and, therefore, when growing on wood cause only minimal loss in strength of that product (Cartwright and Findlay, 1958). However, the appearance of these fungi is unsightly and their presence is allowed only in certain lumber grades and only as a certain percentage of the total volume (NLGA, 1980). Should the lumber become attacked during transit, then considerable financial claims can develop resulting in losses to the producer. Mould and staining fungi will affect the surface characteristics of lumber, particularly adversely affecting its long term durability when painted or stained. This is partly due to the physical presence of the living micro-organisms under the finishing treatment and also because such wood will reabsorb water more readily due to the presence of the fungi (Boocock, 1963).

In the Pacific Northwest the fungi commonly occurring (Eades, 1956; Perrin and Cserjesi, 1978) are species of <u>Trichoderma</u> and <u>Penicillium</u> (mainly green or grey in color), <u>Cephaloascus fragrans</u> (brown mould), <u>Graphium</u> (blue stain), <u>Stemphylium</u> (black mould), and <u>Sporothrix</u> (white), while in Eastern Canada fungi commonly occurring (Unligil <u>et al</u>., 1974) includes species of <u>Alternaria</u> (black), <u>Aureobasidium</u> (black), and <u>Penicillium</u>. Some of these fungi are ubiquitous in their occurrence across Canada, whereas others seem to be limited geographically, which could be connected to the species distribution of softwood lumber across Canada. These fungi vary in their ability to penetrate the lumber, some remaining largely superficial (<u>Trichoderma</u>, <u>Penicillium</u> and <u>Cephaloascus</u>), whereas others will rapidly penetrate the wood (<u>Graphium</u>), causing internal blue or black stains. All vary in their ability to tolerate chemicals and some have the ability to degrade chlorinated phenols (Cserjesi, 1972).

The degree of hazard for mould and stain attack on unseasoned softwood lumber depends on several factors, including the wood species and the climatic conditions. It was recognized by Eades (1956) that species of pine have a sapwood that is rapidly degraded and stained by Graphium sp. The work of Perrin and Cserjesi (1978) also showed that this group of fungi was present in over 50 percent of the isolates made from a study of 39 packages of exported hem-fir lumber.

With the cool to extremely cold winters experienced in Canada, it is not surprising that mould and staining problems are greatest during the summer months, but due to the export of lumber to and through much warmer climates, fungal attack during shipment must be recognized (Roff and Swan, 1973).

Decay Fungi

Previous to the development of packaged lumber in the early 1960's, decay during the shipment of individually packaged lumber was considered unimportant (Eades, 1956). This reflects the drying conditions experienced by indivudally handled pieces of lumber. Today, in the formation of packages of unseasoned lumber, we have created ideal conditions for the rapid deterioration of the wood by wood-destroying fungi. Roff et al. (1974), in a large study of exported packaged lumber from B.C., first noticed decay in spruce-fir and then in hem-fir lumber. After a storage period of 24 months, decay was noted in 30 percent of the spruce-fir, 25 percent of the hem-fir, 25 percent of the lodgepole pine, and 20 percent of the Douglas-fir. In another study of exported hem-fir, Perrin and Cserjesi (1978) noted a rapid development of decay from about seven percent after four months in packages to 28 percent after eight months.

The fungi responsible for this decay vary with the wood species. In the Roff et al. study of 1974, decay organisms identified in spruce-fir included Coniophora puteana (Schum. ex Fr.) Kast., and Polyporus abietinus Dicks ex Fr.; in hem-fir, Lenzites trabea Pers. ex Fr., Fomes pinicola (Sw. ex Fr.) Cooke, Stereum abietinum Pers., and Stereum sanguinolentum Alb. and Sw. ex Fr.; Douglas-fir, Poria monticola Murr. and L. trabea; and in lodgepole pine L. trabea. It is of considereable interest to note that Perrin and Cserjesi (1978) in their study of hem-fir found over 50 percent of the isolates of decay fungi to be Fomes pinicola, thereby confirming an observation made by Eades (1940) much earlier.

The problems of decay in packaged lumber have been described (Roff, 1962; 1971) including the smaller incidence of decay in planed as opposed to rough-sawn lumber caused by the higher surface moisture contents and the more frequent occurrence of moulds at the lumber surfaces in the packaged planed lumber.

Interior decay, or hidden decay, is a condition originating in the standing tree and continuing in the lumber cut from that tree until prevented by suitable drying conditions. It is unlikely that this condition will be detected at the time of manufacture, either by visual or machine-stress grading. Amounts of hidden decay are significant (Roff et al., 1974), with 17 percent and 11 percent being noted for spruce-fir and hem-fir respectively.

Air seasoning of lumber will result in the rapid death of some wood destroying fungi, although others could remain viable but inactive for over one decade (Cartwright and Findlay, 1958). Normal kiln drying procedures will result in the sterilization of lumber, which is an often overlooked advantage of this process.

QUALITY CONTROL

The Council of Forest Industries of B.C. (COFI) and its associate organizations are responsible to an industry that produces over 90 percent of the total sales value of B.C. forest products. Quality control has always been a major concern of COFI, particularly with respect to the export of softwood lumber. Where a two-year storage period is anticipated, then a total chlorinated phenol retention on the lumber surfaces of 0.05 mg/cm^2 is required for over 80 percent of the pieces, with no pieces having less than 0.01 mg/cm^2 (Roff et al., 1974; Cserjesi et al., 1971). Lower retention values could be acceptable where a much shorter storage period is expected. In 1977, COFI began a major survey of the chemical treatment procedures and the chlorinated phenol retention values obtained on the lumber produced by its member mills. It was found that from over 600 samples collected from 22 mills in B.C., only 10 percent of the chlorinated phenol retentions were > 0.05 mg/cm^2, while 36 percent were < 0.01 mg/cm^2. Today, treatment levels have considerably improved in part due to more effective quality control procedures. It is also expected that all surfaces of the lumber be covered, whether applied by dip or spray methods. Each mill is expected to maintain the concentration of the treating solutions at the required level and to provide frequent reports to COFI describing the state of equipment and results from chemical applications. In addition, COFI staff inspect and sample lumber in the field to ensure that retention levels are effective and to determine the required and most effective treatment levels and practices. For the rapid analysis of TCP for qualiy control, the Western Forest Products Laboratory, Vancouver, developed a new, improved analytical procedure (Daniels and Swan, 1979).

In Canada several committees are involved to some degree with the use of chlorophenols by the sawmilling industry. These committees include: the Forest Industry Industrial Health Research Program; the Wood Protection Chlorophenol Task Force; the Transit Protection Task Force; and the Canadian Wood Preservation Association.

Since the inception of these more stringent procedures, there have been marked improvements in equipment design and some degree of increased efficiency as evidenced by improved product quality to off-short markets (Chapotelle, in press).

FUNGICIDES FOR TREATMENT

Sodium tetrachlorophenate is the major active ingredient used in all three commercial sapstain and mould preventives in B.C. to treat unseasoned export lumber. The liquid concentrates are usually supplied to each mill by tanker truck and contain about 24 percent chlorinated phenols in the following approximate ratio:

	NaTCP	NaPCP
Diatox (Diachem Industries Ltd.)	80%	20%
Woodbrite 24 (Van Waters & Rogers Ltd.)	70%	30%
Alchem 4135 (Alchem Inc.)	66%	34%

In addition, Alchem 4135 concentrate contains 1.3 percent of tributyl tin oxide. This latter preventive also is used in Eastern Canada to controls stain and mould on pine softwood lumber.

Alternate chemicals have been tested by Forintek Canada Corp. (Cserjesi and Johnson, in press; Cserjesi and Roff, 1975; Roff and Cserjesi, 1965) as well as by several forest product companies (e.g. MacMillan Bloedel Ltd.). The only alternate fungicide to be used in mill trials in B.C. has been a formulation of copper-8-quinolinolate, evaluated by MacMillan Bloedel Ltd.

METHODS OF TREATMENT

Treating lumber to prevent the growth of mould and staining fungi started in a sporadic basis at about the turn of the century, using simple dipping or hand spraying techniques. With the introduction of anti-stain treatments on a regular basis, dip tanks on the "green chain" were developed (Eades, 1956), which were then followed by the installation of spray systems immediately following the planer. More recently we have seen the development of bulk dipping of lumber packages using a number of techniques, followed by the use of spray systems (Eades, 1956; Roff and Swan, 1973).

Today, two basic methods are used for treating lumber: spraying and dipping.

1. Lumber is sprayed before sorting and/or packaging, and is most practical for the treatment of planed lumber where it is used mainly for this purpose in B.C. Spraying has the advantage of requiring relatively small volumes of treating solutions and the equipment needing only a small area for installation. However, because of the various widths of lumber being treated, an excess of solution is used which requires collection and filtration before it is reused. Plugging of the spray nozzle is a common problem that may not be corrected before several thousand board feet, inadequately treated, have passed through the mill (Cserjesi and Roff, 1966). Recently, new high-pressure spray systems have been introduced that are designed to use less solution but provide

complete coverage. The lumber is sprayed directly as it exits from the planer by one of two different methods:

(a) The lumber is passed lengthwide through a "spray box". This is the most commonly used method for planed lumber because it does not interrupt the production flow. The spray box contains one or two sets of four nozzles, which are arranged to cover all surfaces and edges of the wood uniformly. A spray system may be operated either under high (about 1.4 MPa) or under low pressure, which varies from mill to mill.

(b) The spraying nozzles are arranged across the sorting chain in a "cross chain spray box". This method can be used for spraying either planed or rough-sawn lumber; however, only a few of these boxes are currently operating in B.C.

2. The dipping of individual pieces of lumber clearly give the best protective coverage of chemical solution and require similar amounts of treating solution to the spray system. Such dip systems require little maintenance and are technically simple in operation. The bulk dipping of rough sawn lumber gives relatively good coverage, with less than five percent of the inside surfaces of the packages remaining untreated due to trapped air pockets. However, large volumes (about 40 m^3) of solution are required with inherent potential environmental pollution problems.

Dipping methods can be divided into two types:

(a) Individual pieces of lumber are dipped (before or after packaging). The dip trough is located across the sorting chain and lumber is forced down into the trough, usually by counter-balanced wheels. Solution dripping from the pieces is collected and returned to the treating trough via a back sloping tray. This method is used only by a few sawmills.

(b) Bulk dipping, used mainly to treat rough-sawn lumber, is done by two methods: firstly using drive-in dip tanks, and secondly where the lumber is dipped by automated equipment. Drive-in dip tanks are located where the carrier can drive through or into the dip tank with the lumber. These tanks usually have an entrance and an exit ramp, though in some tanks the carrier must go into the tank, stop and back out. With both types, the waves generated by the carrier must be considered in filling the tank, since the treating solution should only just wash the top of the package.

With automated dip tanks, packaged lumber is delivered to a platform either on rollers from the place of packaging or by a carrier (forklift). After the package is positioned, the platform holding the packages is automatically lowered into the solution and lifted after a short dipping period.

PRESENT POSITION OF CHLORINATED PHENOLS

Although very serious concern has been expressed by both federal and provincial governments in Canada over the widespread use of chlorinated phenol wood protecting chemicals, it seems unlikely that their continual use will be banned in the immediate future. In part, this is because of the unavailability of alternate chemicals which are as effective as chlorinated phenols in the protection of Canada's lumber resource. Within Canada, over the past quarter of a century, the search for substitute chemicals has been intensive, but so far unsuccessful (Cserjesi and Johnson, in press). Similarly, countries around the world have looked, and are looking, for a solution to this problem, but with only limited success (Butcher and Drysdale, 1978). It seems clear that our future fungicides for this purpose will be targetted at specific fungi and will not have the broad spectrum of toxicity that we are used to with chlorinated phenols. This will have the result of requiring mixed chemical treatments, or at least frequent changes of fungicides to cope with outbreaks of different fungi or the development of fungal resistance. This, together with the increased cost of new complex fungicides, will increase the costs of protecting unseasoned lumber very significantly.

Improved handling and application procedures for chlorinated phenols at the mill are under serious consideration. This undoubtedly will reduce the risk of worker contamination and allay some of the current alarm surrounding these chemicals. However, because of the presence of dioxins as contaminants in both the sodium TCP and sodium PCP used in Canada, justifiable concerns remain about their continual use. These problems are covered most thoroughly in the recent economic technical review of the Environmental Impact Control Directorate, Environment Canada (Jones, 1981).

Undoubtedly substitue chemicals for chlorinated phenols will be found and applied to the protection of lumber, but how long this will take will depend very much on the research dollars expended.

ECONOMICS OF PROTECTION

The economic position in Canada is controlled by three factors:

1. chemical cost;
2. capital cost of equipment and installation;
3. operation and maintenance.

All these factors are continually changing, particularly with the recent inflationary trends in this country. However, a study by Nielson (1977) on hem-fir provides the following broad conclusions that would be little changed today:

1. Protection of lumber for two years would require a doubling of the treating costs reported by producers in 1976.

2. Spray systems are lowest in initial cost and operation and maintenance costs, which undoubtedly has led to their widespread use.

3. Dip systems can be considerably more expensive and have the highest operating costs.

In conclusion, it would seem that treatment efficacy increased almost directly with the increased capital cost of the system used. Nevertheless, presently in Canada the protection of unseasoned lumber from biodeterioration during storage and shipment costs the producer less than one percent of the market value of the product.

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