Antisapstain Industry in North America

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Introduction

Lumber from virtually all wood species, both freshly sawn and kiln dried, is susceptible to discolorations as a result of microbial and/or non-microbial factors. Although these discolorations mainly cause a cosmetic, surface damage, it can have an immediate impact on a customer. Lumber discolorations often result in downgrade and in loss in revenue. Lumber discolorations on processed lumber are generally prevented by either kiln drying the wood down to the moisture contents (below 19%) that do not support fungal growth or by surface application of chemicals that inhibit chemical and biological activity. Although kiln drying lumber does remove one of the main fungal growth requirements, water, the lumber will tend to discolor if it gets rewetted during storage and/or transportation. Realistically, wood protection should start at the time of logging. The risk of infection by microorganisms is the highest when the conditions are warm and humid. Once the discoloration in the log is initiated it cannot be reversed with any type of post treatment. The well-established proper log storage techniques have to be utilized to reduce sapstain development during storage. The lumber produced from the logs should be treated with antisapstain chemicals within 24 hours, otherwise many fungi may penetrate the wood beyond the reach of the chemicals during the antisapstain treatment. Wood discolorations that result as a result of fungal infection can be divided into microbial and non-microbial, depending on their causes. The microbial discolorations are as a result of sapstaining fungi, mould fungi and incipient decay. The non-microbial discolorations are due to many factors including: photochemical, biochemical, chemical and brownstain (Kreber, B.).

Mcrobial and Non-microbial Discolorations

The antisapstain industry in N.A. deals with the: (1) preventing sapstain/bluestain and mould on lumber (2) minimizing/eliminating stains on lumber that are caused by chemical reactions (i.e. iron staining) with freshly cut lumber and (3) minimizing/eliminating stains that are caused by enzymatic reactions with the wood. The major form of discolorations on the softwood species are caused by sapstain and mould fungi. Mould fungi (Figure 1) cause discolorations adherent at the wood surface only (Morrell, J). The moulds have vegetative cells (hyphae) which are colorless and thus differ from the pigmented sapstaining fungi. Some of the major forms of mould fungi include *Penecillium, Alternaria, Aspergillis and Trichoderma* (Figure 2). Sapstain/bluestain (Figure 3) is caused by the presence of pigmented fungi infecting the wood. These fungi colonize mainly the sapwood and cause a bluish, greyish or black coloration to the wood. Sapstains grow through ray parenchyma cells and take on wedged shapes or radial streaks

when observed in a log x-section. Although appearing to be stained the wood itself is not stained but the discoloration results from an accumulation of pigmented (brown, black) fungi as they grow within the wood cells. Sapstain is perhaps the more predictable, vectored by known insects and/or originating in the forest floor. Mold spores are "everywhere" – as anyone who has forgotten a sandwich over the weekend knows. Although discolored wood is mainly a cosmetic problem the fungi that cause the discolorations do tend to affect some of the mechanical wood properties. The toughness may be significantly reduced following infection by staining fungi. Sapstaining fungi and moulds increase the permeability of wood by degrading the pit membranes which connect adjacent wood cells by physically boring holes between adjacent wood cells.

Figure 1. Example of Trichoderma Verde mould.

Figure 2. Example of *Aspergillis* (left) and *Penecillium* (right) genus at microscopic levels.

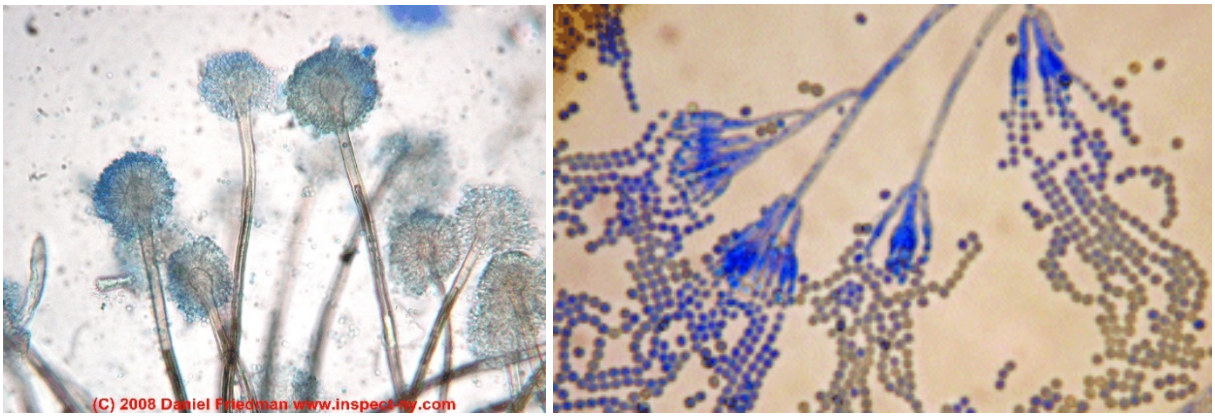
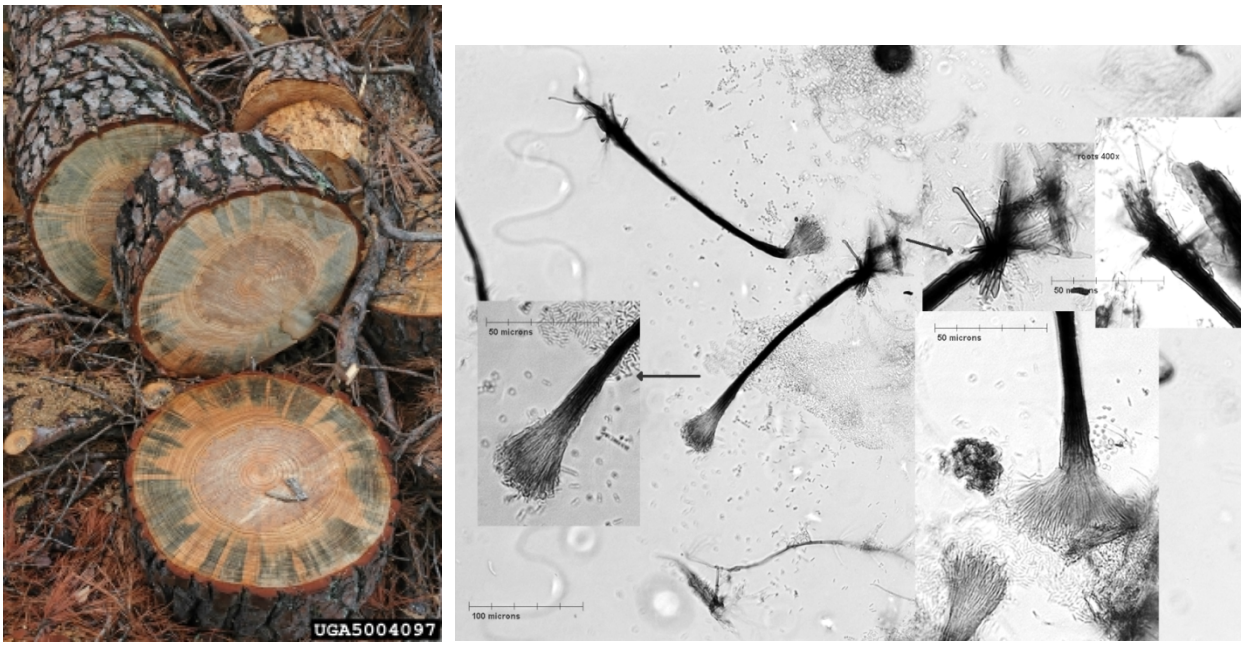


Figure 3. Example of Sapstain in log x-section and microscopic structures of *Ophiostoma* fungal species.



The non-microbial discolorations differ from the mould stains in that no microbial activity is necessary for coloration development. Most of these discolorations develop when green wood is exposed to air (Figure 4). Most of these discolorations are not very well understood but they result from many factors including (Kreber, B): (1) Biochemical - enzymatic reactions that onset the oxidation of extractives to produce discolorations, reactions of metals that react with tannic extractives in wood. Many wood species contain chemical components that undergo oxidation when exposed to air. This process is similar to the oxidative browning of a freshly peeled apple. Certain phenolic substrates are converted to quinones and then polymerized into colored melanins. (2) Chemical – wood containing high levels of tannin can discolor when they come in contact with iron from processing equipment, metal strapping, etc. The iron and tannin react to form a dark colored complex, called iron tannate that creates dark discolorations on green lumber. Examples of woods containing high concentrations of tannins include many oaks and cedars. (3) Brownstaining – even though very poorly understood, it can be caused by water-soluble wood extractives which oxidize and polymerize to form a brown coloration as they migrate to the wood surface. This is another type of oxidative stain that is prevalent in such wood species as white pine, ponderosa pine, sugar pine and hemlock.

Figure 4. Examples of Non-microbial discolorations: Photochemical (top, left), Enzymatic (top, right), Chemical (middle) and Brownstain (bottom).

The reasons why the freshly cut lumber and KD lumber should be treated with antisapstain chemicals include: (1) Preventing lumber degrade and value loss as a result of discolorations caused by mould and sapstain/bluestain fungi. (2) Meeting the customers' expectation to purchase stain/mould-free lumber. (3) Avoiding rejection of shipments and possible financial claims. KD lumber, if kept under cover and dry during storage and shipment will not result in any degrade but the industry experience has shown that the storage practices for KD lumber are very poor and often the KD lumber is not protected from getting rewet. If the moisture contents of rewetted exceed approximately 20% the growth of fungi infecting the lumber is very high. Often, KD lumber is stored outside and exposed to all weather elements prior to being pressure treated. During this storage period the rewetted lumber gets infected and the fungal hyphae grow deep in the lumber. Although mold inhibitors, i.e. combination of isothiazolinones, are used in combination with pressure treatment products, these will only inhibit the fungal growth on wet lumber for certain period of time after pressure treatment. If the pressure treated lumber stays wet for prolonged periods it will be susceptible to mould development due to the regrowth of the deep rooted hyphae that developed during the rewetting of the KD lumber prior to pressure treatment.

Types of Antisapstains

Historically, the antisapstain products consisted of chlorophenates and phenylmercuric compounds. One example of a product containing these was referred to as Permatox 101 (consisted of sodium tetrachlorophenates, sodium metaborate and phenylmercuric acetate). From 1930's to 1987 the protection of lumber was heavily dependent on polychlorophenols (PCP's). They provided excellent treatment and protection against sapstains and moulds as exemplified by their acceptance and use for over 50 years. PCP's came under increasing scrutiny because of their environmental and health side effects. Environment Canada reported that levels of dioxins were abnormally high in workers handling PCP treated lumber. The environmental and health side effects of PCP's resulted in their ultimate abandonment as antisapstain chemicals and all treatment products containing chlorophenates were banned on Dec. 31, 1990 (Miller, D.J.).

Some of the other products that were used in the 1980's included: Busan 1030 (2-thiocyanomethylthio) benzothiazole (TCMTB)), NP-1 (dodecyl dimethyl ammonium chloride and 3-iodo-2-propynyl butyl carbamate), Nytek-GD and PQ-8 (copper-8-quinolinolate), Busan 1009 (Methylene bis thiocyanate(MBT)) and Rodewood 200EC (Azaconazole). Most of these products are still used on hardwoods today. TCMTB and copper-8-quinlinolate have been banned from Western N.A. but are still used in Eastern N.A.

Historical Antisapstains (1930's – 1990)

- Mercurial Compounds
- Chlorophenols + Mercurial Compounds
- Noxtane
- Permatox 100, 101, etc.
- Chlorophenols + Borates

The post-PCP era consisted of heavy use of DDAC and IPBC containing products (i.e. NP-1 and NP-2). Of course, Copper-8-quinlinolate, TCMTB and MTB were also used at this time. Some of the new actives for antisapstain that were introduced at this time included cholorothalonil and carbendazim.

Biocides post-PCP Era

- TCMTB(2-Thiocyanatomethylthio Benzothiazole
- MTB (Methylene Bis(Thiocyanate)
- Cu-8 (Copper-8-Quinolinolate)
- NaOPP (Sodium Orthophenylphenate)
- Carbendazim
- CTL (Chlorothalonil)

In the mid-1990's, propiconazole was introduced as the new and more environmentally friendly antisapstain product since it was used in the agricultural industry for many years. At the same time there was a greater reliance on bi-and tri-active formulations as antisapstain treatments to provide a wider spectrum of fungal inhibition. For example, DDAC was used in combination with borates and in combination with Propiconazole to provide better and longer protection.

Biocides in 1990's

- IPBC (Iodo-Propyl Butyl Carbamate)
- IPBC/QUAT (ddac)
- QUAT/Borates
- Triazoles (Azaconazole, Propiconazole)
- QUAT/Triazoles
- Borax/Sodium Carbonate

In the 2000's there was a greater shift toward use of tri-active antisapstain products to provide even better protection. With greater percentage of the processed lumber coming from the second growth logs, this lumber was more naturally susceptible to fungal infection. In addition, during the downturn in the economy the customer became more stringent on obtaining clean lumber. Even minor blemishes or discolorations came under tight scrutiny and led to some rejection of shipments and even lead to financial claims.

Biocides in 2000's

- IPBC/Triazoles
- IPBC/Triazoles/ADBAC
- IPBC/Triazoles/DDAC

Depending on the wood species and the geographic regions of interest, the antisapstain formulations are custom formulated to provide the optimum protection against mould and stain fungi. Custom blend treatment programs are often used to provide very specific efficacy against specific fungal species that seem to be more apparent in specific situations. Of course, all these custom blend treatment programs are created and used within extremely strict guidelines set out by the Environmental Protection Agency (EPA) in USA and Pesticide Management Protection Agency (PMRA) in Canada.

Antisapstain Treatment Application Systems

The antisapstain treatment application systems mainly consist of dip tanks and spray systems. The dip tanks are preferred method of treatment for smaller, lower production lumber mills. Dipping is the only way to insure uniform contact of the treating solution with all surfaces of the wood. The lumber units can be assembled, banded, trimmed and even paper capped before treatment. The units are handled entirely by chains, rollers and forklifts, eliminating personnel exposure to chemically treated lumber. Automated in-feed, dipping and out-feed systems are capable of handling high throughput. Some of the disadvantages of dip tanks include the excessive sludge build-up in the dip tank overtime and greater amount of drippings from lumber packages. At one time it was believed that the lumber for export be treated by dip treatment only since the export requirements are more critical, where lumber is containerized and subject to extended holding time under severe staining conditions, dip treatment provides the best insurance against claims.

Figure 5. Dip Tank antisapstain treatment systems. Unit Dip Tank (left) and Unit Dip Tank with primary drip area.

Spray systems are normally installed just after the planer but in lumber mills where the rough dimensioned lumber is stored for more than 24 hours prior to planing, a second spray system is installed to provide light antisapstain treatment prior to lumber planing. There are usually two types of spray systems, linear and transverse, that are used in the antisapstain industry. Both types of spray systems use spray nozzles that are used at varying pressures to provide uniform lumber coverage. These spray systems are fitted with mist-eliminator systems that control the mist build-up in the spray boxes. In the past high nozzle pressures were used to apply the antisapstain chemical and it was thought that the greater pressures lead to more uniform lumber coverage. The moderate to low pressure systems (20-60 psi) are now known to provide the better lumber coverage. The biggest benefit of spray systems is the throughput they provide. Some of the lumber mills using spray systems today have throughputs of greater than 2MM bdft/day.

Figure 6. Linear Spray System (left) and Transverse Spray System (right).

Geographic Treatment Differences

Different wood species are ubiquitous to different geographic regions in North America. On the West Coast, the wood species of interest in terms of antisapstain protection include, Douglas Fir, Hemlock, Redwood and to a lesser extent Sitka Spruce. Majority of the antisapstain treatment is carried out using spray systems, both linear and transverse. Depending on the space available for spray system installation together with the throughput requirements and the capital expense allocated, appropriate spray systems are selected to meet the customers' needs. In the Canadian East Coast, the Eastern Hemlock and White Spruce wood species are usually treated in the Province of Ontario. Both dip tanks and spray systems are utilized for antisapstain application in ON. In Quebec, most of the antisapstain treaters are the small mom-and-pop operations that use Dip Tank Treatment Systems only. Majority of the lumber that is treated in this region is

hardwood lumber including Maple, Birch, Red Oak, White Oak, Poplar, Ash and Red Pine. In the US SE, the Southern Yellow Pines, including Slash Pine, Loblolly Pine and Long-leaf Pine are predominantly treated. There are distinct differences in the type of antisapstain treatments that are required for each of these geographic regions and one treatment does not fit all. Therefore, the design of treatment for each region and species of wood often takes extensive experimentation and trials to find the most effective treatment.

Summary

The antisapstain industry is concerned with providing chemical treatment formulations for microbial based and non-microbial based stains. The microbial stains include the superficial mould stains, caused by various types of mould fungi, and deep discolorations that are caused by sapstaining fungi, such as the ones belonging to the Ophiostoma genera. Both types of these discolorations can be well controlled with currently used antisapstain formulations. It should be clearly understood that these chemicals only provide preventative methods to control such infections and do not offer cures to eliminate the pre-infections. The non-microbial stains include those caused by oxidation of extractives within the wood, reactions of wood extractives upon contact with iron and the least understood brownstains. Regardless of the type of discoloration, they can result in major lumber degrade and heavy profit losses.

The currently used antisapstain treatments contain multiple actives that may include: DDAC, IPBC, Propiconazole, Borates and Benzyl Quats. These treatment systems are used in combination with other synergists and ancillary products to provide the most effective type of wood protection against lumber discoloring microorganisms. The antisaptain treatments are designed to fit treatments for specific wood species in a specific region of N.A. In certain regions of N.A. mould fungi are more prevalent and in other regions, sapstain fungi are more prevalent. Certain types of treatments are more effective against moulds and the others are more effective sapstainers. One type of treatment does not fit all.

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