ABOVE GROUND VERSUS GROUND CONTACT DECAY HAZARDS

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Summary

Higher wood decay hazards in ground contact compared to above ground are well known but perhaps not well understood. The key differences between ground contact and above ground are consistency of wood moisture content and greater nutrient availability in soil which influences the greater activity of bacteria, detoxifying fungi and soft-rot fungi in ground contact. Above ground decay tends to begin around water traps whereas in ground contact it begins at or near groundline. However, the biggest difference is in the inoculum potential of the invading fungi. Above ground colonization is primarily by spores while in ground contact it can be by spores mycelium and mycelial strands. Soil-inhabiting, strand-forming, copper-tolerant, wood-rotting basidiomycetes are the greatest threat to treated wood. Above ground shell treatments can be effective if the preservative has some mobile bio-available components that move into checks and stop spore germination. In ground contact deep penetration is important to resist colonization by soft-rot fungi and strand-forming basidiomycetes. *Gloeophyllum* species are the most common fungi decaying wood well above ground due to their tolerance of solar heating and low moisture contents. This is true even in wood treated with copper-based preservatives because the spores of copper tolerant fungi are not producing oxalic acid and are therefore not copper tolerant. There are many uses of wood which are literally above ground but where conditions may be more like ground contact or may change to become ground contact. The American Wood Protection Association use category system is being modified to address this. Canadian standards already do so to some extent but may need further improvement. A range of standard test methods is required to account for all situations a preservative may encounter. None of these are unrealistically aggressive. In developing new preservatives, preservative manufacturers need to understand the differences between in- and above-ground. They need to test new preservatives in ground at sites with strand-forming copper-tolerant basidiomycetes and test new preservatives above ground using a range of test methods including decking tests. When building above ground structures, users of treated wood need to check for conditions similar to ground contact.

Introduction

The higher decay hazard in ground contact compared to above ground is well known, and has long been codified in wood preservation standards, but is perhaps not well understood. The key differences between pure ground contact and pure above ground exposures are summarized in Table 1. There are linkages among these factors. The consistency of moisture content influences the greater activity of bacteria, detoxifying fungi and soft-rot fungi in ground contact. A supply of soil nutrients may also be needed for the soft-rot fungi to thrive (Herring et al 1997). Much more information on the factors influencing decay can be found in the textbooks by Zabel and Morrell (1992) And Eaton and Hale (1993). An overview of these topics is provided by Morris (1998, 2001).

Table 1 Key Differences Above vs in Ground

Influences on decay	**Above Ground**	**In Ground**
Moisture conditions	High variability	Low variability
Nutrient supply	Poor	Good
Detoxifying iron	Minimal	In reducing conditions
Inoculum type	Spores only, unless mycelium or strands grow from adjacent wood	Spores, mycelium and strands
Bacteria	Limited activity early	Continuous activity
Detoxifying fungi	Intermittent activity	Continuous activity
Soft-rot	Only under unusual conditions	Common
Basidiomycetes	Ubiquitous as spores	Ubiquitous as spores and Localized in soil as strands

In an attempt to make sure the right loading and penetration of preservative is used for the anticipated exposure, decay and termite hazards and consequences of failure, the uses of treated wood have been classified into five use classes with sub-classes in wood preservation standards in most parts of the world. The ISO system adopted in Canada can be summarized as shown in Table 2. However the boundaries between above ground and ground contact are not always that distinct.

Table 2 Simplified Description of Use Classes

Use Class	**Exposure**
UC 1	Above ground indoors, dry
UC 2	Above ground indoors, damp
UC 3.1	Above ground outdoors, coated
UC 3.2	Above ground outdoors uncoated
UC4.1	In ground, typical soils
UC4.2	In ground, severe conditions
UC5	Marine exposure

The primary focus of this paper is to discuss the differences between UC3.2 and U4.1 and the situations where these boundaries are blurred. Some of this information comes from the literature but much of it comes from observation of the performance of untreated and preservative treated wood in field tests reported to the CWPA in a series of 24 papers, the latest of which was presented at the 2015 meeting (Morris and Ingram 2015). Decay processes above ground are discussed in Section 2 and the decay processes in ground contact are discussed in Section 3. Section 4 discusses situations where the exposure changes or is less easily defined and Section 5 discusses the relevance of some of the most commonly used test methods published by the American Wood Protection Association.

Above Ground

Without exposure to rain, the moisture content of wood well above ground, will typically be too low for decay, normally around 16% equilibrium moisture content, other than in tropical climates. The moisture content of kiln-dried wood needs to rise to 25% and higher for decay initiation by basidiospores and small mycelial fragments (Wang and Morris 2010). Consequently, the locations vulnerable to decay are those where additional wetting occurs. Where wood is in direct contact with permeable building materials, such as concrete or brick, close to the ground, moisture may wick up into the wood. Other than those few cases, the additional moisture comes in the form of precipitation. Most of the rain that falls onto a piece of wood above ground will flow right off again which is one reason why Scheffer’s Climate Index uses days with detectable rain rather than amounts of rain to model relative decay hazards above ground (Scheffer 1971). It also does a remarkable job of parsing data on a climate with warm, dry summers and cool wet winters versus a climate with hot, wet summers and cold, dry winters and accurately predicting equivalent rates of decay at the two locations (Morris and Wang 2011). The most vulnerable points in wood construction outdoors above ground are where some of that rain can be slowed down and trapped particularly where there is permeable end-grain. Examples include the tops of posts, notches, joints, and damaged areas. Examples without end grain but with prolonged water trapping include large metal connectors and most importantly checks on the top surfaces of horizontal boards and beams. Downward sloping cracks in the sides of beams can also be highly vulnerable and are often not considered when protection by design is being used to protect glulam beams. Condensation from dew or fog can also provide limited sources of moisture but this can make a difference to the decay hazard in warm coastal areas with an offshore cold current, such as California (Dost 1992). Often it is not the part of the wood most exposed to rain that decays but the part that stays wet longest after rain events. Impediments to drying include joints between multiple large wood members, large metal connectors, excessive flashing or self-adhering membrane (designed to deflect rain), and paints/coatings.

Brischke and Meyer-Veltrup (2015) found that, in the absence of water traps, specimen size is not correlated with wood moisture content or decay in above ground exposures. They recommend using test methods with specimens close to those used for real-life structures in order to mimic crack (check) formation as closely as possible.

Joints between wood components are particularly vulnerable to decay because they a) trap water, b) draw water up into the end-grain, c) are slow to dry out, particularly if there are metal plates on the outside, d) permit longitudinal colonization by fungi which is more rapid than lateral colonization due to the wood structure and e) permit growth of fungi from one component to another. Furthermore, they are the most critical point on a structure because that is where loads are transferred. Inspection for decay should always focus on joints.

The routes of access for fungi to the unpenetrated interior of shell-treated commodities are much the same as the sources of moisture trapping (see above). Locations where spores have time to germinate and grow deep enough into the wood to avoid surface re-drying after rain events are also those locations where drying is impeded (see above). Joints and checks on the upper surface of horizontal components are particularly vulnerable. Early colonizing fungi may increase the permeability of the wood increasing moisture uptake. Once some decay has occurred, there may be increased trapping and retention of water which facilitates more rapid decay. The nutrients available to fungi colonizing wood above ground are mostly limited to those present in the wood itself and those that might be available from other building materials in contact with the wood (Hastrup *et al.* 2014).

Time course isolations of microorganisms on pine sapwood reveal that the sequence of colonization: bacteria, primary moulds/staining fungi, soft-rot fungi, wood rotting basidiomycetes and secondary moulds, is much the same above ground (Carey 1980) as in ground contact (Clubbe 1980) though there are major differences in species composition and prevalence. The early-colonizing organisms exclude the wood-rotting basidiomycetes until the freely available starches, sugars and proteins have been used up and the only carbon sources left are within the lignocellulose matrix. Little work has been done on the colonization sequence in heartwood which has very little in the way of easily assimilable carbon sources. Modified lignin resulting from decay is incorporated into soil and continues to degrade extremely slowly but relatively little work has been done on this process by wood biodeterioration scientists. They have little interest once the wood is non-functional from a structural or aesthetic point of view. At this stage, wood residues become the purview of soil scientists.

The sources of decay fungi colonizing wood well above ground are generally limited to spores (Savory and Carey 1976, Schmidt and French 1978, Bjurman 1984, Fougerousse 1984, Hegarty and Buchwald 1988, Croan 1994, 1995) which are suspended in air currents, washed from the air by rain or vectored by insects. It is not impossible for small mycelial fragments to be blown by air currents or vectored by insects, but these, like spores, will have relatively low inoculum potential (resilience and ability to colonise). Basidiospores form part of the airspora year-round but their prevalence increases in the fall when conditions are particularly conducive to formation of new fruiting bodies. In large rotting logs, wood-inhabiting basidiomycetes may produce fruitbodies earlier than soil-inhabiting fungi due to the more reliable moisture supply, and continue to fruit later due to the temperature-buffering effect.

Spores have limited reserves of carbohydrates and their metabolism is not geared up for decay of wood. The decay process produces oxalic acid which can detoxify copper (Murphy and Levy 1983) but, in the absence of the capacity for decay, the spores of even copper-tolerant wood-rotting basidiomycetes are not copper tolerant (Choi *et al.* 2002). Basidiospores are generally not as resistant to biocides as mycelium (Morton and French 1966, Schmidt and French 1979, Choi *et al.* 2002, Woo and Morris 2010) although the reverse is true with some preservatives (Savory and Carey 1976). Similarly borates stop decay but do not stop spore germination (Hegarty and Buchwald 1988). Deep preservative penetration may not be as important above ground as it is in ground contact provided the preservative has mobile components that can move into checks and is sufficiently bio-available to prevent spore germination (Choi *et al.* 2001, 2002, 2004, Morris *et al.* 2004, Woo and Morris 2010). This has been shown to occur with chromated copper arsenate (CCA) and with micronized copper preservatives but seems to be less effective with copper-ethanolamine based preservatives due to lower bio-availability of the leachable copper (Stirling et al 2015). Some of the carbon-based preservatives similarly show no efficacy in this manner (Woo 2010). However, Canadian wood species with shell treatments of copper-containing preservatives have shown very good long term performance in above ground field tests (Morris and Ingram 2011, Morris et al. 2012, Morris and Ingram 2013).

Choi *et al.* (2003) found soft-rot fungi colonizing around checks in treated decking that had exposed untreated wood but, presumably, been protected against germination of basidiospores by mobile copper. There was no detectable soft-rot damage showing conditions were unsuitable for decay by this group of fungi. However, these fungi were capable of tolerating and accumulating copper so they may have a long term effect in neutralizing the efficacy of copper in stopping germination of basidiospores. Herring *et al.* (1997) has previously proposed a similar hypothesis for decay by mixed cultures of copper tolerant and non-tolerant soft-rot fungi. Choi et al (2003) only detected wood-rotting basidiomycetes in 15-years old CCA-treated decking and this was *Gloeophyllum sepiarium* which is not copper tolerant. On the other hand, the occupation of this niche by soft-rot fungi may keep basidiomycetes out for a period of time, as was hypothesised to explain the situation with low-level borate treated L-joints (Morris *et al.* 2008). While soft-rot fungi can colonize wood above ground, they are unable to cause rapid decay unless the moisture content is consistently high as, for example, in framing lumber in leaky wall systems (Wakeling 2015).

Gloeophyllum species, particularly *G. sepiarium,* and further south in North America, *Gloeophyllum trabeum* and *Gloeophyllum striatum,* are by far the most common fungi decaying wood exposed outdoors well above ground. This is likely because they are relatively tolerant of the high temperatures than can be caused by solar heating and they are tolerant of low wood moisture contents. *G. trabeum* certainly seems to be able absorb water from the atmosphere since mass balance on the decay process shows higher moisture contents than can be explained by initial moisture content prior to colonization and water produced from conversion of wood components to fungal biomass, CO_2 and water (Viitanen and Ritchskoff 1989).

Issues that may contribute to premature failure of treated wood, particularly decking, above ground are discussed in more detail by Stirling and Morris (2015). In addition to the situations discussed in Section 4, these may include:

1. Low weight treatments that leave untreated perishable sapwood to be exposed in checks.
2. Failure of mobile copper from ACQ and CA treated wood to stop spore germination in checks.
3. Establishment of copper-tolerant fungi on un-penetrated sapwood and juvenile heartwood
4. Retentions lowered to co-biocide levels that can’t stop mycelial attack on treated zone.

Until perhaps 30 years ago, preservative loadings for above ground uses were determined based on laboratory tests (AWPA 2015c) and short term ground contact stake tests (AWPA 2015a). While a number of field tests have been developed over the past 25 years for above ground exposures (See Section 5), the laboratory tests relied on in North America still use actively growing mycelium of wood-rotting fungi as the inoculum. There have been numerous attempts, over the past 40 years at least, to develop methods to assess the resistance of treated wood to germination of basidiospores (Savory and Carey 1976, Schmidt and French 1978, Bjurman 1984, Cymorek and Hegarty 1986, Croan 1994, 1995). However, as far as we are aware, FPInnovations is the only organization currently capable of testing wood preservatives and treated wood products against basidiospores from a range of species, including copper-tolerant fungi, in an Accelerated Field Simulator (Morris *et al.* 2009) and in laboratory tests (Stirling *et al.* 2015).

Ground Contact

When wood is put into the ground the first thing that happens is that it absorbs soil water which will contain the same macro and micronutrients used by plants, and probably some bacterial cells. Under reducing conditions the water may contain Fe^{2+} ions which react with and detoxify arsenic in CCA or ammoniacal copper zinc arsenate (Morris 1992, 1994). The continuously moist conditions in soil are more conducive to preservative leaching than above ground.

Deep in the soil, the wood moisture content may be so high that oxygen diffusion is limited and decay is extremely slow. Subsoil also tends to be infertile. Above ground the moisture content of the wood will typically be too low for decay, in the absence of water trapping (see Section 2). Topsoil tends to be much more fertile supplying more nutrients and a broader range of fungal colonizers. Just below ground level air temperature fluctuations are moderated and the moisture and oxygen content will be just right so that is where decay proceeds fastest. That is not necessarily where decay got in. It may have arrived in the form of a spore in an open check just above ground where the majority of the circumference is dry enough for checking but capillary movement up the check creates suitable conditions for spore germination (Morris *et al.* 1984).

There have been limited studies on naturally occurring preservative-detoxifying bacteria and fungi in soils (*inter alia* Dubois and Ruddick 1997, Wallace and Dickinson 2006, Obanda and Shupe 2009, Woo et al 2010). These organisms are believed to be ubiquitous; many are able to degrade organic biocides and some may complex copper using organic acids. While wood-decaying bacteria are much more active in soil than in above ground, they are only of economic importance where wood-rotting basidiomycetes and soft-rot fungi are excluded, typically in anaerobic conditions (Eaton and Hale 1993). Under these circumstances, their decay is extremely slow, typically taking a hundred years or more. That is the next generation's problem. The much greater activity of soft-rot fungi in soil is the biggest difference in decay between above ground and ground contact. They are uniformly present in soil, many are preservative tolerant and they have been found to cause serious decay of hardwoods with poor preservative microdistribution (Greaves 1977). Soft rot most commonly progresses gradually into the wood from the surface in contact with soil or along checks, but if the fungus is preservative tolerant it can penetrate right through the treated zone (Zabel et al 1991). Unless preservative retentions are very low or the soil has been amended with organic matter and nutrients (Butcher 1984) their decay in treated softwoods is slow, taking decades. If a preservative controls basidiomycetes and moderates soft rot an acceptable life can result. This can be termed "mature failure".

Soil-inhabiting, strand-forming, copper-tolerant, wood-rotting basidiomycetes are the greatest threat to treated wood. They have bundles of hyphae that provide mutual protection. They grow through soil and over inert substrates. They have high inoculum potential to colonize and decay starts immediately, producing oxalic acid which can detoxify copper (Murphy and Levy 1983). They decay wood rapidly, taking a few years. This can be termed "premature failure". Examples of such fungi at FPInnovations test sites include *Leucogyrophana pinastri* and *Antrodia serialis* at our Maple Ridge test site, *Oligoporus balsameus* and *Serpula himantiodes* at our Petawawa test site (Morris *et al.* 2012), and *Coniphora olivacea* at our former Kincardine termite test site (Morris et al 2014). Other soil-inhabiting, strand-forming, wood-rotting basidiomycetes that attack naturally durable wood, and may attack wood treated with copper-free preservatives, include *Tapinella atrotomentosa and Hypholoma fasciculare* at our Petawawa test site. These types of fungi and soft-rot fungi actively growing from a resource in the soil may be able to penetrate through treated zones without having to decay the wood to gain nutrient value. If the treated zone is shallow, they can flourish in the unpenetrated interior. Consequently good preservative penetration is key to protection of wood in ground contact, to moderate soft rot and resist soil-inhabiting, strand-forming, wood-rotting basidiomycetes. If preservative penetration and loading is sufficient, these fungi may cause limited surface decay that fails to progress deep into the wood. Presumably they are then supplanted in this decayed zone by aggressive secondary moulds, as defined by Clubbe (1980). Canadian wood species with shell treatments of 5 mm or more have shown very good long term performance in ground contact field tests (Morris and Ingram 2011, Morris *et al.* 2012).

The decay hazard for wood on the ground can sometimes be worse than in the ground. It is not always the part with most soil contact that rots first. In a retaining wall the lower timbers are wetter but the checks are closed. The top timber is wet below but dry above and open checks allow spores in.

More detailed information on decay of treated wood in ground contact is given by Wakeling and Morris (2014).

Situations Where the Exposure Changes or is Less Easily Defined

Conditions of exposure of wood products inevitably change over time. Most importantly, soil levels always rise; that is why we have archeological digs. Landscapers add mulch, gardeners dig in organic matter, trees drop leaves. For this reason the National Building Code of Canada states: Structural wood elements shall be pressure-treated with a preservative to resist decay, where the vertical clearance between structural wood elements and the <u>finished</u> ground level is less than 150 mm. Shrubs and vines planted around a deck start out small but are soon creating high relative humidity conditions around the wood components and slowing their rate of drying after rain events. These same plants, and nearby trees, shed leaves onto the deck. One tries to sweep them off but inevitably some go down between the cracks and, depending on construction, may stay there. Decks installed directly on concrete slabs are particularly susceptible to build up of detritus beneath them.

The structure may be constructed with poor ventilation in the first place. Boards too close together, fascia boards at the edge and construction of a waterproof roof for storage space under a deck can dramatically reduce the ability of deck boards to dry out after rain events. Planters placed directly on the deck will supply and trap moisture underneath them. Additional moisture may be supplied by sprinkler systems that spray the deck while watering adjacent flowerbeds or irrigate planters on the deck, and by hot tubs inserted in the deck.

Where moisture conditions are more consistent, *Gloeophyllum* species which are not copper tolerant can be outcompeted by other species such as *Postia placenta* which are copper-tolerant. Where wood is placed directly onto permeable building materials such as brick and concrete, close enough to soil level for moisture wicking, conditions can be highly conducive to not only wood decay fungi but also the bacteria and early colonizing fungi that can detoxify carbon-based co-biocides. In addition, soil-inhabiting, strand-forming, copper-tolerant, wood-rotting basidiomycetes may be able to grow from buried wood or highly organic soil over or through these materials to access the wood. It is even worse where people put treated wood in direct contact with untreated wood that is not naturally durable. This can arise from deciding to save money on components not thought to be at risk of decay, running out of treated wood and substituting untreated pieces, or placing untreated wood planters on a deck. “China cedar” planters are a classic for this. While old growth *Cunninghamia lanceolata* heartwood was durable, plantation material is only moderately durable (Xing *et al.* 2005) and has a wide non-durable sapwood. If copper-tolerant, wood-rotting basidiomycetes are growing from buried wood or from untreated wood in direct contact with treated wood they will already be producing oxalic acid which can detoxify the copper.

It has only recently been widely recognized that there are numerous situations where wood components may be above ground but have many of the conditions of ground contact. This may have contributed to premature failures of decking in the southern USA. There have also been premature failures of decking in the US Virgin Islands where tropical conditions create high above ground decay hazard due to constantly high moisture contents and warm temperatures. There have been no similar widespread premature failures in Canada as far as we are aware as of this writing. Canada has generally lower decay hazards, except on the coasts. Our wood species are resistant to wetting and treatment and consequently have high surface loading which means more mobile copper.

As a result of the issues in the USA the American Wood Protection Association is considering several modifications to its use category system which was developed earlier than the ISO system on which Canada’s use class system is based. The following changes are proposed.
The following added to UC3B

> See Note 1 under UC4A ground contact for components that may be physically above ground components but that are required to be treated to for ground contact. This includes components that are difficult to replace and critical to the structure or that may be exposed to ground contact type hazards due to climate, artificial or natural processes or construction.

The following added to UC 4A

Note 1. The following components for exterior above ground use shall be treated to Ground Contact UC4A or higher requirements:

a) When there is a reasonable expectation that soil, vegetation, leaf litter or other debris may build up and remain in contact with the component.
b) When the construction itself, other structures or anticipated vegetation growth will not allow air to circulate underneath the construction and between decking boards.
c) When components are installed less than six inches above ground (final grade after landscaping) and supported on permeable building materials
d) When components are in direct contact with non-durable untreated wood, or any older construction with any evidence of decay.
e) When components are wetted on a frequent or recurrent basis (e.g., on a freshwater floating dock or by a watering system).
f) When components are used in tropical climates.

We have dealt with some of these issues in Canada where our CSA O80 standard already states: The intended use of Product Groups A and B shall not involve direct contact with untreated wood except naturally durable western red cedar, eastern white cedar and yellow cypress or exposure to conditions under which the material could reasonably be expected to be colonized by mycelial growth of fungus directly from soil or via moisture-wicking building materials.

There is a another major issue in the marketplace which is that Big Box stores do not sell 2 inch material treated to ground contact loadings. They don't want 2 Skus of the same size. This issue can only be addressed by education of the retailers and consumers.

Relevance of AWPA Test Methods

One of the earliest AWPA test methods and one still regarded as critical for listing of a new wood preservative is the stake test (AWPA 2015a). Exposure to natural soils creates the potential for exposure to all the parameters described above. However, soil-inhabiting, strand-forming, copper-tolerant, wood-rotting basidiomycetes are not present at all test sites, and where present their distribution is not typically uniform (Morris and Ingram 1991, Preston *et al.* 2008, Clausen and Jenkins 2011, Raberg *et al.* 2013). Some sites have known hot-spots where preservatives at loadings that perform well elsewhere, fail prematurely. The other mainstay test method of the American Wood Protection Association is the soil block test (AWPA 2015c) which exposes wood to pure cultures of wood-rotting basidiomycetes, including copper-tolerant species, growing on wood in contact with sterile moist soil. Some have argued this test method is overly aggressive since it is possible to find one or more fungi capable of severely degrading wood treated with ground-contact loadings of well-established preservatives, for example *Fibroporia viallantii* and CCA. On the other hand, where these same fungi occasionally crop up in real life, wood products that we would deem properly treated can fail prematurely. Fortunately these fungi are relatively rare. However, two others among our standard test fungi, *Postia placenta* and *Coniophora puteana* (and relatives) are very common and we standardize loadings ineffective against these fungi at our peril. Others say this test method is unrealistic for above ground applications since it involves soil and actively growing mycelium. Since the soil is sterile, it has no preservative-detoxifying fungi or soft-rot fungi. Since the test wood block is on a feeder strip on the soil, the diffusion of nutrients is limited. Furthermore, the prospect of mycelium growing onto treated wood from untreated sapwood in contact with soil is exemplified by the deck decorated with a "China cedar" planter, described above. There is no AWPA standard test method that is guaranteed to expose treated samples to preservative-detoxifying fungi, soil nutrients and strands of soil-inhabiting copper-tolerant wood rotting basidiomycetes though a promising method has been studied (Morris *et al.* 2014).

One of the earliest outdoor above ground test methods was the L-joint test (AWPA 2015b), but this was really designed for preservatives intended for coated millwork applications, though there was the potential for leaf litter accumulation on the test rack. Nevertheless it was used for a broader range of treatments until the Horizontal Lap-joint test (AWPA 2015d) was standardized. The lap-joint test is a pure above-ground test method and the water trapping is limited so it only gives moderately rapid results even in high-rainfall areas like windward Hawaii (*inter alia* Preston *et al.* 2011). In temperate climates the decay is very slow to develop. In contrast, the ground-proximity decay test (AWPA 2015e) very much represents some of those above-ground uses which are more like ground contact. The treated samples are:

a) In direct contact with untreated wood.
b) Sitting on concrete blocks that wick up water.
c) Surrounded by a wood frame that impedes ventilation
d) Covered with a shade cloth that further impedes drying
e) Exposed to soil brought up by insects

This condition pretty much represents a worst case above ground exposure for through-treated sapwood samples but it is not conducive to the checking that would expose unpenetrated wood in shell-treated material. In contrast the decking test (AWPA 2015f) represents a more realistic decay hazard for deck-surface boards with high humidity on the underside of the deck and drying conditions on the top surface. These conditions and the larger size (Brischke and Mayer-Veltrup 2015) induce the checking that can permit access by basidiospores to unpenetrated wood if the preservative is present at too low a loading, insufficiently mobile, or not bio-available after redistribution. It is a commodity test, requiring large samples considerable space and long exposures (10 years or more in temperate climates) to yield useful data (Morris and Ingram 2013). However, use of this test method might have more rapidly revealed some of the issues with premature failure of southern pine decking, permitting corrective steps to be taken earlier.

Conclusions

- When building above ground structures, check for conditions similar to ground contact
- In developing new preservatives, understand the differences between in- and above-ground.
- In developing new preservatives consider performance against spore germination as well as mycelial colonization.
- Field test new preservatives in ground at sites with strand-forming copper-tolerant basidiomycetes.
- Field test new preservatives above ground using a range of test methods including decking tests.

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