

Poplar and preservative treatment – a literature review

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Recommendations

Research is required on distribution patterns of water-based preservative in poplar.

The process will require:

1. Kiln dried timber
2. Extending pressure period to refusal (2-3 hours).
3. A Bethell full cell process, with at least 30 minutes vacuum (100 kPa) applied before fluids are added to the vessel, followed by flooding while maintaining a vacuum of -80 kPa or better. Then pressure of 1400 kPa, held for 2-3 hours (until refusal), then drained before applying vacuum of -85 kPa or better, held for minimum 20 minutes
4. For research into penetration and distribution variables, use water with a dye-containing aqueous solution (0.05% rhodamine B). For deployment, a treatment charge could use CCA treatment in the first instance, potentially followed by ACQ and micronised copper to compare distribution patterns between these water-based preservatives.

Following successful preservative distribution and an appropriate schedule, durability testing will be required to assign a hazard classification according to retention levels. This step is critically important.

Preservative treatment of poplar

The European standard BS EN 350-2:1994 categorises poplar sapwood as easily treated and heartwood as difficult to treat, but the species exhibits an unusually high level of variability. In contrast, Tesoro & Chang (1976, as cited in Thompson & Koch, 1981) found cottonwood (*Populus deltoides*) heartwood to be more permeable than sapwood, which is not found in softwoods.

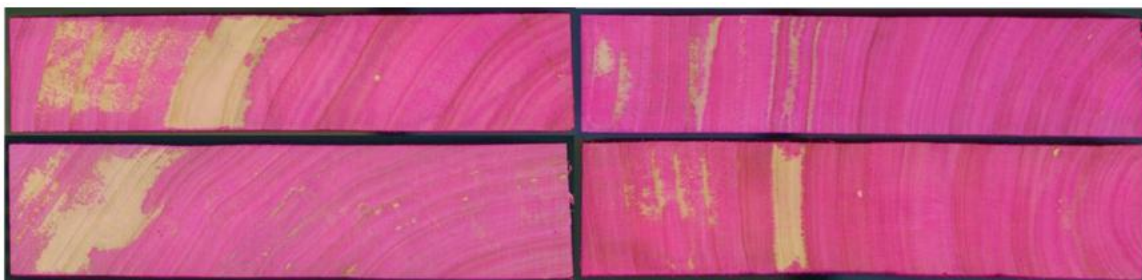
In wood-treatment contexts, the term "refractory" is sometimes used to describe a wood zone that is highly resistant to absorbing chemical preservatives. Although poplar wood is considered to be easily treatable, refractory zones may be present and lead to insufficient presence of preservatives (Van Acker et al. 2024).

The micro-distribution pattern of preservatives within the wood structure (i.e. intracellular deposition of preservatives) varies depending on the wood species, and increasing the retention of some preservatives such as CCA does not change their distribution pattern in the cell walls (Tarmian et al. 2020). Thompson and Koch (1981) suggested that uneven distribution of preservative may be more important than preservative retention in poplar, and that this could be more important than preservative loading in overcoming issues with decay in preservative-treated hardwoods.

Preservative penetration into most hardwoods is via their vessels. Although many hardwoods exhibit improper and uneven penetration and distribution of impregnation fluids, Buschalsky et al (2022) reported that the cause for this has not been fully researched yet for poplar. In hardwoods, the heartwood vessels may become blocked by pith-like growths called tyloses. Low permeability is governed by anatomical barriers such as vessel blockage by tyloses in hardwoods (Zhang et al 2026). Despite the typically low levels of tylosis reported for poplar, Buschalsky et al. (2025) found a significant degree of tylosis in a range of poplar genotypes, particularly in the transition zone between sapwood and heartwood, identifying tylosis and tension wood as key factors in fibre pit encrustations that reduced fluid uptake. Williams et al. (1986) surmised tyloses and tension wood as the cause of unpenetrated zones in water-borne (Bethell process) pressure-treated poplar. The tyloses obstruct water flow in the heartwood and also form in the sapwood (particularly in the 10mm closest to the surface) after sawing. They also found the presence of tension wood in New Zealand grown poplar, which tended to be site rather than species specific.

Impregnation of poplar with a dye-containing aqueous solution (0.05% rhodamine B) provides a method for testing different pressure treatment schedules. Buschalsky et al (2025 a) used a 2 h vacuum followed by 5 h of pressure at 1 MPa. and produced images illustrating heterogeneous distribution patterns in poplar wood. The light red hue of rhodamine B allows for macroscopic and microscopic visualisation of the distribution of the absorbed impregnation solution within the wood, allowing both impregnated and non-impregnated regions to be identified and correlated to schedule.

Fluorescent dye-bearing water solutions, such as rhodamine b, are suitable to visualize the uneven impregnation solution distribution in poplar wood on a macroscopic level.



In specimens appearing well impregnated by the naked eye and using DLM, microscopic FLM images revealed frequently small unstained areas within otherwise well impregnated areas (Buschalsky et al. 2025a).

After treatment, some components of water-soluble preservatives are diffused into wood over time (Tarmian et al. 2020).

White rot and brown rot are of concern in wood-structured indoor environments (Pace Labs 2026). White rot fungi are the most important causes of decay in hardwoods and these can be tolerant of certain preservatives (Thompson & Koch 1981). Softwoods also tend to be subject to decay from the copper resistant fungus *Rhodonina placenta* (brown rot).

Soft rot tends to negatively impact external structures (Pace Labs, 2026) and wood in ground contact (Thompson & Koch 1981). Soft rot also tends to attack hardwoods treated with water-borne salt preservatives (Thompson & Koch 1981).

"Poplar, being a hardwood, is susceptible to soft rot and requires higher preservative retention than pine to get similar durability. If I remember correctly Tony Bergervoet estimated that preservative retention for hardwoods like poplar would need to be increased by 25% or more to reduce soft rot susceptibility. Hence I would recommend that poplar should not be used for ground contact (H4) uses without a substantial increase in minimum retention requirements. H4 treated poplar posts had significant soft rot after five years in one of our service tests and were likely to fail within 15 years. In relatively dry, above-ground situations, H3 treatment should be OK." (Diahanna O'Callahan, BSI, pers. comm via email 4/03/2025)

Poor performance of hardwoods in ground contact has been attributed to skewed CCA distribution patterns among vessels, fibres, and ray tissues in the fibres of some hardwoods, while those with uniform preservative distribution performed satisfactorily in field tests (Thompson & Koch, 1981). Where Concentrations of copper, chromium, and arsenic were much higher in ray cells than in fibres (poor penetration of the fibre cell walls by the preservative), treatment failed to protect the timber from soft rot.

Pressure treatment

Vacuum/pressure treatment is the industrial scale treatment of choice for wood. Using higher treatment pressures and extending the pressure period allows some preservatives to better penetrate difficult-to-treat wood species (Tarmian et al. 2020), with moderate pressure for moderately long pressure periods usually being more effective at improving penetration than higher pressure for shorter periods.

Empty cell processes (e.g. Reuping or Lowry processes) tend to be less effective than full-cell processes (e.g. Bethell) for preservative penetration of refractory species (Tarmian et al. 2020).

Pressure treatment of hardwoods with CCA is commonly done to refusal, when gauges indicate no more preservative is being taken up by the wood (2-3 hours) (Slahor 1999). Williams and Simpson (1986) treated poplar posts to refusal with a full cell process, which resulted in full sapwood penetration and acceptable distribution. However, although solution uptake was high in kiln-dried posts, uptake was not satisfactory in air dried posts. Williams and Simpson (1986) also found "Any necessary level of preservative retention may be achieved by adjustment of the solution strength" and "individual hardwood species must have an added safety factor to take into account their susceptibility to soft-rot fungi". Williams (1976) and Page (1995) found that where pressure treatment period was reduced to 138 minutes and one hour respectively (i.e. not to refusal), penetration was "patchy".

Yun et al. (2019) found that immersion with a vacuum of two hours at 0.5 MPa preceded by 30 minutes of -0.1 MPa significantly improved volume loading of preservative in poplar. This pre-vacuum phase deeply extracts trapped air from tracheid lumens and pores, eliminating pneumatic resistance that impedes fluid entry (Zhang et al. 2026).

Zhang et al. (2026) found that vacuum pressure influences the impregnation efficiency of refractory wood, and pneumatic resistance within tracheid lumens could be overcome effectively only under high-vacuum conditions (-90 kPa). This deep negative-pressure treatment clears air pockets occupying pores at the microscopic scale, creating an unblocked pathway for subsequent deeper nano-colloid penetration. Establishing a high-gradient negative-pressure environment (e.g., -0.08 MPa) is required to open microscopic fluid pathways and ensure deep penetration in refractory wood.

Fixation, an important process to remedy leaching of preservatives, can be related to the wood's microstructure (Tarmian et al. 2020). This review did not explore fixation and leaching of preservatives from poplar. This subject could be explored if even distribution of preservatives is consistently achieved.

Alternatives to CCA

Nitrogen-based compounds added to copper preservatives include micronized copper azole (MCA) and alkaline copper quaternary (ACQ). These do not contain arsenic and chromium and can achieve similar performance to older chromium-based systems without the environmental risks. However, these are more corrosive to fasteners than CCA and leaching can be an issue.

The ammoniacal component of Alkaline copper quat (ACQ) theoretically has the potential to improve penetration into refractory woods (Slahor 1999). ACQ has been demonstrated to have good permeability into wood, but the active ingredient is soluble in water and depends on the level of fixation. Fixation, an important process to remedy leaching of preservatives, can be related to the wood's microstructure (Tarmian et al. 2020). Improving the fixation of preservatives in poplar remains unresolved (Yun et al. 2019) but Yun et al. showed that fixation was improved with ethanol extraction and microwave pretreatment.

Micronised copper traditionally uses finely ground copper carbonate microscopic particles suspended in water, which do not require fixing because they are not soluble in water. This treatment is gaining popularity but may have less ability than traditional soluble copper-based preservatives to deeply and uniformly penetrate into wood, because depending on the species particles may be too large to penetrate the cell wall microporosity (Tarmian et al, 2020).

Moisture content

A greater retention and uniform distribution of nano-particle preservative was found in oven dried poplar wood compared to 25% MC under vacuum/pressure impregnation (Tarmian et al. 2020). Wytwer (1995) found non-pressure penetration of water-based preservative increased with moisture content, from 12% MC to 50% MC, but retention decreased as moisture increased. Both heartwood and sapwood had similar rates of permeability.

Slahor (1999) found that CCA treatment of yellow poplar (*Liriodendron tulipifera*), a diffuse porous species similar to poplar, was significantly better at 12% moisture content. "The drier the wood the deeper the penetration"(Thompson & Koch 1981).

New preservative formulations

Recently, a new micronised copper formulation using copper sulfide has been developed (Guo et al. 2025), which was successfully tested on poplar timber 20mm x 10mm samples, impregnated under vacuum and kept at a vacuum of -0.08 MPa for 15 min. It was kept at 0.8 MPa pressure for 60 min. Leaching resistance and the effect on wood decay fungi was demonstrated on poplar samples, highlighting the potential for commercialisation of this preservative formulation. Retention was higher for poplar than pine, but leaching was higher in poplar than for pine. More work is required on penetration, retention and distribution of preservative on full size poplar timber.

Nanoscale silver–copper particles were tested on poplar using vacuum-impregnation and was effective against fungal decay (Wang et al. 2024).

A non-volatile ionic binding carrier (TANO) is a specialized adjuvant system used in the TRU-CORE® wood preservation treatment (Fishers Timber Treatment). The carrier works alongside water-based solutions under a vacuum/pressure process. Fishers Timber Treatment claim Tru-Core locks the active ingredients into the wood fibres and enables full-depth penetration even in refractive species.

Pretreatment

Pre-treatment and post treatment methods could improve preservative permeability. A range of permeability enhancement technologies are available for combining with vacuum pressure impregnation, including enzymatic hydrolysis, steam pre-treatment, microwave pre-treatment and green-solvent treatment (Zhang et al. 2026).

Steaming

Steaming can be used to improve the penetration of preservatives, but treatability of some species does not improve with steaming, and over-steaming can reduce wood strength (Tarmian et al. 2020). Williams (1976) suggested steaming prior to treatment could remedy poor preservative penetration into poplar wood. Satchell (2023) reported patchy preservative distribution from green (fresh undried) posts steamed prior to pressure treatment using an alternating pressure method (APM) and a radiata pine treatment schedule.

Heat treatment

Yun et al. (2019) found that heat treatment has little effect on the volume loading, but microwave pretreatment improved the permeability of poplar wood. Yellow poplar showed better treatability using heated ACQ solution (Slahor, 1999).

Non-pressure methods

Non-pressure methods have been investigated, such as steeping, cold soaking and hot-and-cold bath, which exposes the wood to preservatives in an open vessel. Conditioning of stock prior to treatment is usually by air drying (Thompson & Koch 1981).

In hot-and-cold bath process, a partial vacuum created in the outer layers of wood provides deeper capillary penetration of preservatives (Tarmian et al. 2020).

In cold soak processes some control over retention by permeable species can be exercised by adjusting the period of immersion. North American data suggests that cold soaking of cottonwood (*P. deltoides*) for four days would achieve preservative retention for ground-contact service (Thompson & Koch 1981).

Rassouli et al (2017) found that penetration of copper increased with immersion time in all directions, with similar levels of preservative as a full cell pressure treatment after 10 days. Rasouli et al (2017) also reported that during long term dipping, absorption of copper can occur on wood constituents, with the outer layer containing more copper than indicated by the uptake of preservative solution. Additionally, strength of the solution decreases with the number of impregnation cycles.

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