Nanotechnology: A Novel Approach to Prevent Biocide Leaching

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Abstract

Newer wood preservative formulations are formulated without chromium and arsenic with the intent to reduce negative environmental impact. However, the removal of chromium from biocide formulations also leaves them more susceptible to leach. Leaching of biocides from preserved wood can negatively effect ecosystems, particularly wetlands, and can potentially reduce the useful lifetime of wood and preserved wood products. This is undesirable both from an economic standpoint and from the standpoint of increased stresses to forest ecosystems that must meet the needs of a growing U.S. and international demand for wood products. The objective of this research project is to use nanotechnology as a means to deliver and "fix" copper and organic biocides into wood to eliminate or reduce the loss of biocides to leaching. Nanotechnology, which is routinely applied to controlled delivery and release of pharmaceuticals, has been too costly to use in many other areas, but new technologies and new commercial uses for nanotechnology is producing lower cost and more efficient methods allowing nanotechnology to become more cost effective. The increased awareness of ecological and economic consequences of biocide leach has increased the importance of developing ways to reduce biocide loss. This project seeks to develop a practical approach to incorporate wood preservatives into polymeric nanoparticles that can be introduced into wood with the effect of controlling the biocide release rate to reduce or eliminate loss to leach.

This research project will prepare biocide-containing core-shell nanoparticles using redox initiation to graft a hydrophobic acrylic monomer, methylmethacrylate, (MMA) to a water-soluble biopolymer, which in aqueous media gives a core-shell nanoparticle structure as shown in Figure 1.

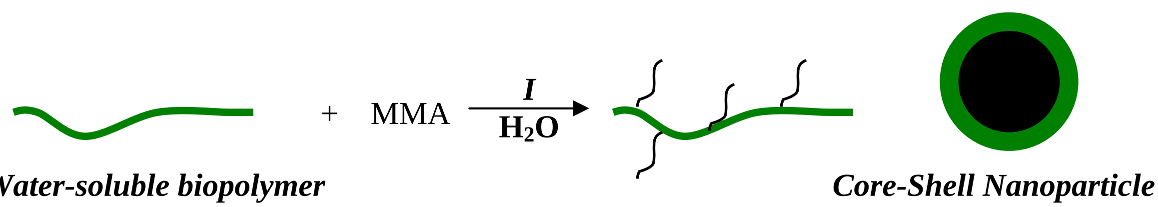

Figure 1. Redox-initiated graft copolymerization of water-soluble protein, which self-assembles into a core-shell nanoparticle.

The key synthetic targets of the project are testing best methods to prepare core-shell nanoparticles with good stability and a loading and high delivery efficiency into wood. The major hypotheses to be tested are: (1) a core-shell nanoparticle structure can be used to produce a stable aqueous suspension of biocide-containing nanoparticles; (2) a suitable release rate of organic and inorganic biocides can be attained using a core-shell nanoparticle structure than can control the biocide release rate to increasing the biological efficacy of the biocide and so increase the protected lifetime of treated wood; (3) wood preservation can be achieved using less biocide than currently required using today's technology; and (4) encapsulation of biocides within diffusion-controlled nanoparticles can reduce or eliminate biocide leaching.

The EPA determined that in 2000 the U.S. wood preservatives market was 809,000,000 pounds[1]. Although use of some types of wood products is declining, the total demand and market value for treated wood products is increasing. In 2003, the wood preservatives industry stopped using chromated copper arsenate (CCA), which has resulted in significant changes in the U.S. wood preservatives market. Although in 2005 this market was

$500 to $600 million[2], the nature of these wood preservatives is changing, and although discontinuing use of CCA may have removed one ecological issue associated with wood preservative use at the same it may have aggravated another, biocide leach. Newer wood preservative formulations do not “fix” to wood. Although low solubility biocides are often favored because of leaching, this is an inadequate response. Even low solubility biocides will leach, resulting in negative economic and environmental consequences.

Loss of wood preservatives to leaching not only leaves the wood product vulnerable to biological attack, reducing its useful lifetime, but the leached biocide has negative consequences to sensitive environments, especially wetlands and other moist environments where leaching will be more rapid. If leaching can be reduced or eliminated not only will wetlands be less at risk, but demands will not be made on forest ecosystems to replace wood that was lost because preservative was lost to leaching.

Incorporating biocides into polymeric nanoparticles allows the bulk of the biocide to be safely stored within the nanoparticle’s interior where it is protected from loss to leach and random degradative processes. The polymeric nanoparticle functions first as a protective reservoir but also serves as a controlled release device where the biocide is release by a predominantly diffusion controlled process, where the rate of diffusion is strongly dependent on the hydrophobicity of the polymer[3,4].

By using a solid polymer as a biocide carrier even water-insoluble biocides can be delivered into wood without a surfactant, which by itself reduces leaching. By controlling the hydrophobicity of the polymer the release rate of the biocide can be kept low, ideally sufficiently low so that only the minimum amount of biocide needed to preserve the wood is ever outside the nanoparticle at a given time. By avoiding the use of surfactants and maintaining a low diffusion rate of biocide to a level to maintain biological efficacy but reduce risk of loss to leach the effect of fixation can be mimicked.

Expected benefits to be gained by incorporating biocides within a polymeric nanoparticle reservoir include all the beneficial effects of preventing contamination of ecosystems through leaching, extending the service life of wood and wood products, and the ability to effectively protect wood products at lower levels of biocide use.

References

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