

Wood Protection Research Council

Research Priorities 2013

Carol A. Clausen
Frederick Green III
Grant T. Kirker
Stan T. Lebow



Abstract

This report summarizes presentations and comments from the inaugural Wood Protection Research Council meeting. Research needs for the wood protection industry were identified and prioritized. Methods for successfully addressing research needs were discussed by industry, academia, and association representatives.

Keywords: Wood protection, durability, biodeterioration, accelerated testing, molecular ID, decay fungi, preservation, nanotechnology

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Wood Protection Research Council

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Carol A. Clausen, Supervisory Research Microbiologist

Frederick Green III, Research Microbiologist

Grant T. Kirker, Research Forest Products Technologist

Stan T. Lebow, Research Forest Products Technologist

Forest Products Laboratory, Madison, Wisconsin

Contributors

- Amy Blodgett, USDA Forest Products Laboratory, Madison, Wisconsin
- Bessie Woodward, USDA Forest Products Laboratory, Madison, Wisconsin
- Carol Clausen, USDA Forest Products Laboratory, Madison, Wisconsin
- Colin McCown, American Wood Protection Association, Birmingham, Alabama
- Dallin Brooks, Western Wood Preservers' Institute, Vancouver, Washington
- Dan Imholte, Bell Lumber and Pole Company, New Brighton, Minnesota
- Dave Webb, Creosote Council, Butler, Pennsylvania
- David Clemens, Wheeler Lumber, LLC, Des Moines, Iowa
- Dragica Jeremic, USDA Forest Products Laboratory, Madison, Wisconsin
- Frederick Green III, USDA Forest Products Laboratory, Madison, Wisconsin
- Grant Kirker, USDA Forest Products Laboratory, Madison, Wisconsin
- Michael H. Barnes, Mississippi State University, Mississippi State, Mississippi
- Jeff Miller, Treated Wood Council, Washington, D.C.
- Jeremy Williams, Timber Products Inspection Inc., Conyers, Georgia
- Jim Gauntt, Railway Tie Association, Fayetteville, Georgia
- Jim Herdon, Hoover Treated Wood Products, Inc., Thomson, Georgia
- John Horton, Osmose, Inc., Griffin, Georgia
- Jonathan Schilling, University of Minnesota, St. Paul, Minnesota
- Jun Zhang, Osmose, Inc., Griffin, Georgia
- Katie Jenkins, USDA Forest Products Laboratory, Madison, Wisconsin
- Kevin Archer, Viance, LLC, Charlotte, North Carolina
- Kevin Ragon, Southern Pressure Treater's Association, Starkville, Mississippi
- Lehong Jin, Viance, LLC, Charlotte, North Carolina
- Mark Mankowski, American Wood Protection Association, Birmingham, Alabama
- Mike Freeman, Wood consultant, Memphis, Tennessee
- Patrick Schleisman, Hoover Treated Wood Products, Inc., Thomson, Georgia
- Peter Laks, Michigan Technological University, Houghton, Michigan
- Rachel Arango, USDA Forest Products Laboratory, Madison, Wisconsin
- Richard Ziobro, Osmose, Inc., Griffin, Georgia
- Sarah Dunlavy, Bell Lumber and Pole Company, New Brighton, Minnesota
- Stan Lebow, USDA Forest Products Laboratory, Madison, Wisconsin
- Steve Halverson, USDA Forest Products Laboratory, Madison, Wisconsin
- Steve Shields, Lonza Wood Protection, Atlanta, Georgia
- Susan Diehl, Mississippi State University, Mississippi State, Mississippi
- Susan Thomason, Lonza Wood Protection, Atlanta, Georgia
- Ted Ladoux, Western Wood Preservers' Institute, Vancouver, Washington
- Vicki Worden, Worden Associates, Camden, Maine
- Vina Yang, USDA Forest Products Laboratory, Madison, Wisconsin

Executive Summary

Almost 400 million cubic feet of preservative-treated wood is produced and consumed in the United States annually, with residential applications representing a significant percentage of the treated wood market. Since historic changes in 2004 with the voluntary withdrawal of chromated copper arsenate from residential applications, the wood preservation industry has undergone more than a decade of dynamic changes. There have been market-changing challenges with

corrosion, environmental concerns, preservative tolerance by decay fungi, and mold growth on treated products along with fears that replacement preservative systems may face environmental scrutiny. Societal pressures for environmentally compatible preservatives are difficult to solve swiftly because it takes many years to conduct long-term performance evaluations to vet a new preservative. Improved methods are needed to more rapidly assess the potential for a preservative to provide long-term protection from decay and insects. As part of the mission of the Forest Service, viable treatment options for non-traditional, underutilized wood species are needed to develop value-added markets for woody biomass to reduce the wildfire hazard.

Chemicals used to protect wood from deterioration by fungi and insects have generally been broad-spectrum biocides that have been discovered by the traditional screening approach. A more logical approach is the development of selective and targeted biocides by defining the target first, characterizing that target, and then designing inhibitors based on the mechanism of action of the defined biotarget. Despite substantial progress in elucidating the biochemistry of wood degradation, biochemical targets for fungal inhibition have seldom been described. Discovering the mechanism of preservative tolerance(s) in economically important fungi and insects will enable us to design preservative systems that neutralize, block, prevent, and eliminate the preservative tolerance. Development of a genetic database of microbial activity during the process of wood deterioration will give us a better understanding of the microbial ecology of *in vivo* biodeterioration; in other words, precisely how and when decay or insect attack is initiated. A molecular database would provide a myriad of capabilities to the wood preservation community. For example, researchers could characterize decay risks for a particular location, define the prevalence of tolerant fungi on a national and international basis, and determine the influence of preservative exposure on the ecology at test plots. The next generation of novel wood protection methods may incorporate nanotechnology for design and/or controlled delivery of biocides for improved durability of building materials, with an emphasis on engineered composites. Nanotechnology may also play a vital role in the development of water-resistant coatings and treatments for the prevention of fire. Results from basic research on genetic analysis, biochemical processes, nanotechnology, and characterization of biotargets will lead to technological developments that extend the service life of wood and wood-based materials in all major end uses emphasizing environmentally friendly methods.

To this end, the USDA Forest Products Laboratory (FPL) hosted a 1-day meeting aimed at identifying the current research needs of the wood preservation industry and fostering collaborative efforts to partner in those research needs. Comprising the Wood Protection Research Council (WPCR) were representatives from the wood preservation and forest

products industries, affiliated associations, and universities with forest products curricula. These stakeholders encompassed representation from research and development, manufacturing, distributing, treating, and product oversight and consumers of treated wood products. This report provides a summary of the critical and current research needs of the wood protection community expressed by the presenters and attendees of the WPCR.

Introduction

An important limitation to the selection of wood as a building material, and a prime cause of user dissatisfaction, is its vulnerability to biodeterioration by fungi and insects under certain conditions of storage and use. Efforts to protect wood from biological degradation are among the earliest research at the Forest Products Laboratory. This research has successfully reduced the demand for lumber from our National Forests by reducing the need to repeatedly replace existing wood products.

Wood protection has undergone dynamic changes since the industry voluntarily withdrew CCA from most residential uses and new products were introduced to the marketplace. To bring a new preservative to the marketplace, a considerable amount of performance data need to be obtained. Current laboratory methodologies to determine the durability of test specimens are insufficient, and long-term field testing is required to ensure that a treatment is effective. Improved accelerated test methods to predict performance would reduce the time needed for the development and acceptance of new preservatives. Potential improvements for accelerated testing may include selection of test fungi, techniques to detect incipient stages of fungal decay, methods to properly assess durability of wood plastic composites, use of rapid laboratory bioassays for screening, statistical analysis, and field tests that could measure loss in mechanical properties.

Targeted protection systems and novel advances in wood protection from nanotechnology could replace the broad spectrum biocides traditionally used to inhibit decay fungi. The most logical approach to develop targeted biocides is to take advantage of unique physiological attributes of decay fungi, such as their ability to sequester metals through production of oxalic acid or natural tolerance to preservatives. Discerning and describing these mechanisms may enable us to design specific, targeted inhibitors to control decay and circumvent preservative tolerances that are common in brown-rot basidiomycetes.

Repair costs associated with structural damage caused by Formosan (*Coptotermes formosanus*) and Eastern subterranean (*Reticulitermes flavipes*) termites and protection measures to prevent termite damage are now estimated to exceed \$10 billion annually. Economic losses resulting from the northward spread of major species of subterranean termites are projected to grow because of changes in climate, underscoring the importance of protecting structural

building components from this pest through the development of environmentally safe and effective biocides. There are already ecologically important indicators that changes in climate are affecting subterranean termite habitat. An understanding of colony behavior, distribution patterns, and characteristics of colony decline will hasten dispersal mitigation efforts. Basic research on the role of microbes in termite colony health could lead to targeted treatments for termite infestations for in-service wood products. New techniques for delivering baits that target the colony, such as trap, treat, and release (TTR) offer alternatives to current methods that rely on repellants and barriers. Targeted baiting would be environmentally advantageous as the effective rate of treatment uses much lower quantities of termiticide than conventional methods.

Objectives

The objectives of the Wood Protection Research Council (WPRC) were to

- present the current wood protection research focus of Forest Products Laboratory,
- present the current research needs of associations affiliated with wood protection,
- identify areas of critical research needed by the wood protection community, and
- foster collaborative efforts among contributors of the WPRC to address critical research needs.

Research Summary

Following are summaries of research presentations (see Appendix).

Stan Lebow, Forest Products Laboratory

One of the challenges in wood protection is predicting long-term performance with relatively short-term tests. Variability within exposure conditions, organisms present, and within the wood itself can make it difficult to design appropriate short-term tests or to interpret their results. Although a range of standard test methods are available, the extent of acceleration represented by these methods is not well understood. For example, the primary laboratory leaching method, which immerses small cubes is overly conservative and is difficult to relate to leaching from wood used above-ground. Research is being conducted to evaluate the use of simulated rainfall and larger specimens so that leaching results can be more readily related to in-service leaching conditions. Although stake tests have been used to evaluate wood preservative efficacy for many years, the role of stake size and test duration in predicting future performance are not well understood. Recent research suggests that the extent of acceleration achieved by using smaller stakes varies substantially, and that statistical modeling approaches show promise in better understanding the predictive value of stake tests. Methods of accelerated evaluation of above-ground

durability have proven particularly challenging because exposure conditions vary so greatly. Continued research is needed to better understand the species of fungi responsible for above-ground degradation, as well as the moisture conditions that exist within in-service structures.

Frederick Green, Forest Products Laboratory

Targeted inhibition of fungal decay and termite damage are now within reach of wood protection research. Production of chitin synthetase inhibitors for control of subterranean termites represents proof of concept. Most brown-rot fungi that exhibit copper tolerance have a common underlying mechanism, which is oxalic acid production and precipitation of copper oxalate. Recent research at Forest Products Laboratory has described the key pathways and enzymes responsible for fungal oxalate production within the tricarboxylic acid and glyoxalate metabolic cycles. We plan to investigate the elimination of key pathways that will obviate copper tolerance, rendering this important group of decay fungi impotent. By similar means and methods, termites live in a subterranean environment conducive to the production of molds and other pathogenic microorganisms. Unregulated microbial growth should be harmful or fatal to termite colonies. We hypothesize that subterranean termites have evolved mechanisms to control overgrowth of bacteria, molds, and decay fungi. Interfering with the precise mechanisms of microbial control should result in multiple new avenues that will permit microbial overgrowth and elimination of the colony. Targeted molecules can readily be distributed by the social behavior and grooming activities of the termite colony. Proof of this concept is seen by the dusting of termites (trap, treat, and release) with N,N-hydroxylamine and collapse of an entire colony of *R. flavipes* in central Wisconsin (Green et al. 2014). We conclude that targeted inhibition of both fungi and termites can extend the service life of wood and wood products in an environmentally friendly manner while protecting and extending our sustainable natural resources.

Grant Kirker, Forest Products Laboratory

Improved and existing methodologies are being used for sensitive and accurate DNA-based detection and identification of wood associated fungi from a wide variety of substrates including treated wood. Currently, a procedure called terminal restriction fragment length polymorphism analysis (commonly abbreviated as T-RFLP) is being used to create DNA-based profiles for characterization and identification of wood-decay fungi. T-RFLP has previously been used to identify fungi in above-ground test samples (Räberg et al. 2009) and also to characterize changes in bacterial (Kirker et al. 2012a) and fungal (Kirker et al. 2012b) communities in treated wood. DNA fragment profiles are currently being created and compiled for wood-decay fungi commonly occurring on treated and untreated wood products. These profiles will be used to create a database for rapid diagnostic identification of common wood-decay fungi even from

mixed cultures. These tools are being developed to assist industry and private entities in routine identification of common wood-degrading fungi. Concurrently, data on biodiversity and distribution of wood-decay fungi from field stake surveys are being collected to provide better estimates of service life of wooden products in a given geographic region of North America by properly documenting the prevailing fungal species in a given climatic zone, which is mostly overlooked in most estimates of biodeterioration hazard classifications.

Carol Clausen, Forest Products Laboratory

Advances in wood protection based on nanotechnology are being developed to improve resistance of wood products to biodeterioration, reduce environmental impacts from chemical leaching, and resist UV degradation. Nanoparticles of copper, zinc, boron, or silver were used to vacuum treat Southern Pine and evaluated for biological resistance, leach resistance, and photostability. Both nano ZnO and CuO were leach resistant, and nano ZnO particles provided photostability against UV degradation and acted as a termite toxicant. In a study on biocide encapsulation, it was demonstrated that an organic biocide could be encapsulated in a self-assembling hyperbranched nano-polymer matrix. Thermogravimetric analysis showed that a subsequent incremental increase in temperature would trigger the incremental release of the biocide. Nanopolymer matrices can be designed to hold on to an encapsulated biocide until a specific change in the physical environment, such as elevated heat or moisture, releases the encapsulated biocide. Another nanoencapsulation technology used inert nanotubules of clay loaded with organic biocides for targeted delivery and slow, controlled release of biocide. Biocide-loaded nanotubules inhibited mold growth on MDF, gypsum, and OSB. The unique properties of nanomaterials enable endless innovative improvements in the field of wood protection for surface treatments, pressure treatments, or as direct additives to furnish for engineered wood composites.

Jeff Miller, Treated Wood Council

With funding from the Treated Wood Council, researchers conducted life-cycle assessments (LCAs) to evaluate the environmental impacts resulting from the growth, harvest, manufacture, use, and disposal of treated wood products in comparison to alternative construction materials. The LCAs were conducted in accordance with ISO standards, critically reviewed, and published in scientific journals. LCAs have been completed for ACQ-treated decking, borate-treated framing lumber, creosote treated railroad ties, pentachlorophenol-treated utility poles, CCA-treated marine piles, and CCA-treated guardrail systems. With few exceptions, treated wood compared favorably to alternative products across a range of impact categories.

Kevin Ragon, Southern Pressure Treaters' Association

The Southern Pressure Treaters' Association (SPTA) is an organization that is made up of industrial wood preservers located east of the Rocky Mountains who produce industrial preservative-treated wood products that are critical to U.S. electrical, transportation, and industrial infrastructure. Because of the recent de-rating of the strength values of southern yellow pine (SYP) (*Pinus* spp.) lumber by the American Lumber Standards Committee, the producers of SYP poles wanted to conduct testing of the SYP pole resource to confirm that the strength values for SYP poles shown in ANSI O5.1, the national standard for wood poles, were still valid. SPTA conducted full-size destructive testing in cooperation with the Mississippi State University Forest Products Laboratory to obtain strength values for untreated green southern yellow pine poles following the cantilever test method in the ASTM D 1036 standard specified for the development of strength values by ANSI O5.1. These green poles were randomly selected from stock obtained throughout the SYP production range of eight states: Texas, Arkansas, Louisiana, Mississippi, Alabama, Georgia, South Carolina, and North Carolina. Poles were placed in a fixture and a transverse load was applied and measured until failure. Measurements of horizontal deflection and longitudinal movement of the load point were recorded during each test. Based on the measured breaking loads, computations of the modulus of rupture (MOR), and the modulus of elasticity (MOE) were made. These green MOR strength values were adjusted downward for the strength reduction associated with conditioning prior to treatment in accordance with ANSI O5.1. The adjusted MOR strength value was above the 8,000-lb/in² value found in ANSI O5.1 for SYP. Although the average rate of growth of the test specimens was much higher than that of the specimens tested in the 1960's, the limitations in the ANSI O5.1 standard on growth rate and summerwood percentage in each piece performed their intended function of ensuring that the poles produced to the standard today still exhibit the historic 8,000 lb/in² MOR strength attributed to SYP poles.

Dallin Brooks, Western Wood Preservers' Institute

The Western Wood Preservers' Institute (WWPI) formed the Environmental Performance of Treated Wood Research Coop (TWRC), consisting of nine full members representing industry associations and chemical suppliers and 36 associate members representing wood treaters. The TWRC conducted an extensive Best Management Practices (BMP) verification study using different combinations of wood species and preservatives to evaluate the effects of rainfall, coatings, snow, and pre-washing on preservative leaching and copper migration. Additional BMP verification tests have been initiated that will evaluate polycyclic aromatic

hydrocarbons (PAHs). A need exists for more demonstration projects using Screening Level Assessment and BMPs. In conjunction with Washington State Department of Transportation, WWPI conducted a study on the performance of CCA-treated hem-fir guardrail posts after 20 years in service compared to new posts. Performance properties included residual preservative retention, residual flexural strength, and decay analysis. Results from this study showed that most posts were properly treated and those that were properly treated had lower percent decay with fungi commonly detected in small decay pockets. Flexural properties were similar for new and used posts, and most posts exceeded American Association of State Highway and Transportation Officials (AASHTO) minimum standards.

Jim Gauntt, Railroad Tie Association

The Railroad Tie Association (RTA) was first organized in 1919 in St. Louis, Missouri, to address timber conservation issues and develop tie and wood preservative standards. At that time, creosote and zinc chloride were the preservatives used to protect railroad ties. Today, the RTA has 3,334 members and its mission is to improve wood life cycle costs. It regulates three tie-related specifications in conformance with AREMA and provides a forum to the public and members for the exchange of technical information. The biggest problem in 2013 facing the otherwise uneventful tie marketplace was supply, in part due to record rainfall in the southeastern U.S., a rebound in the housing market, and an increase in exports of U.S. hardwoods to China. It is expected to take 18–24 months before the marketplace equalizes. Beyond regulations, the RTA also sponsors research projects. A current major research project on the economics of dual treatments has shown that dual treatment of ties with creosote and borate or copper naphthenate and borate led to a significant extension of tie service life even in areas where decay was the primary source of failure. In zone 5, the most severe decay hazard zone, where 95% of ties fail between 8.5 and 25.5 years, dual treatment would extend service life to 18 to 54 years. Another significant research project sponsored by the RTA is the alternative wood research project (AWRP). The goal of the AWRP is to assess the relative performance of new and existing preservative systems in refractory and non-refractory wood species. Phase I included corrosion, decay, and termite resistance and dimensional stability at two field test sites with annual inspections up to 4 years to date. Phase II will evaluate new treatment and process options. A variety of in-track treatments including gels, pastes, rods, pads, and sprays were evaluated for 14 years. Borate treatments in the form of rods placed in holes drilled on either end of the plate arrested decay and were very effective as was borate paste, fluoride pads, and copper–borate pads, but borate rods placed in unused spike holes was not effective at preventing decay. It was concluded that supplemental in-track treatments during normal maintenance would increase the service life of ties by arresting incipient

decay and protecting against other wood destroying organisms. Supplemental in-track treatments would also increase the life of reused ties and minimize the spread of pests.

Dave Webb, Creosote Council

The Creosote Council focuses on product stewardship through their website, online educational materials for creosote treatment workers and long-term research projects such as the 1958 Creosote Co-op study and the Creosote Dermal study. Results of the Creosote Co-op study showed that representative creosotes P1/P13 and P2 gave excellent performance after 50 years in southern yellow pine posts treated to 96 kg/m³ (6 lb/ft³). Good correlation between soil block test and long-term field tests suggested that laboratory tests with creosote systems were good predictors of field performance. The objective of the Creosote Dermal study was to estimate dermal absorption of creosote in humans using rats as a model and *in vivo* dermal exposures to both neat creosote and creosote-treated wood for 8 hours. The liquid creosote was spiked with ¹²C-PAH markers and determination of radioactivity in exposed rats showed maximum absorption 21 days after dosing was 8.86%. Human absorption is 1/8 of rat absorption equating the results to a human creosote dermal absorption of 1.1%, an acceptable exposure according to the EPA. Eight-hour dermal exposure to P1/P13 treated pine and P2 treated red oak coupons resulted in a total absorbable dose in rats of 1.54% (= 0.19% in humans) for pine and 1.81% (= 0.22% in humans) for red oak.

Colin McCown, American Wood Protection Association

The American Wood Protection Association (AWPA) was first organized in 1904 at the St. Louis World's Fair primarily to develop standards for treated wood and secondarily as a forum for the technical exchange of information. It currently has 623 members, 17 committees, and 172 standards. AWPA is funded through membership dues, sales of standards, and sponsorships. The association holds two annual meetings: a scientific meeting with an emphasis on research and a technical meeting with an emphasis on committee meetings to address proposals, additions, revisions, deletions, and task force items. Forest Product Laboratory scientists play a critical role in the AWPA through service on committees, committee leadership, contributions to standards activities, unbiased participation in committee deliberations and proposals, research to develop evaluation methods, science delivery, assistance with the technical forum and meeting organization, and networking with academia, industry, treated wood specifiers, and end users.

Purpose of the Report

This report summarizes feedback generated during the Wood Protection Research Council meeting, both from presenters and attendees, about critical research priorities. The

Council meeting was designed to foster informal candid discussion on research needs. The top three research priorities from individual attendees were solicited in written form to facilitate equal opportunity for attendees to express their opinion without conflict or feedback. The main objective is to document and rank those priorities and discuss how to address the priorities.

Discussion Framework

Participants were asked to openly discuss critical research needs. Examples of topics were offered to initiate the discussion, and participants were encouraged to suggest additional topics.

A facilitated discussion included the following topics:

- Accelerated test procedures
- Expanded testing of new preservatives
- Minimum specified retention–Variability exists in treated wood retentions both within and between charges.
- Continued support of cutting edge fundamental research
- Dipped and spray-coatings–residential lumber protection from fire, mold, and decay
- Growing importance of the impact of treated wood products on environment
- Life cycle assessment of wood and wood products
- Efforts to focus on general promotion of wood products
- Nanotechnology–wood protection
- Composites–durability
- Forest fires–utility pole protection
- Cycle changes, new treatments
- Capabilities at FPL
- Controlled moisture across the surface of the wood

Prioritized Research Needs

Participants were asked to anonymously write their top three prioritized research needs on an index card. The facilitator emphasized that an individual’s research needs could be those that were discussed and listed in the discussion framework or research needs that were not discussed. Index cards were collected and the number of responses for each research need was recorded. In a few instances, similar research needs were listed together. In three instances, a participant provided more than three prioritized research needs and when that occurred, all research needs were included in the ranking. Research needs were assigned points (1, 2, 3...) and ranked based on the average number of points per response with the lowest number receiving the highest priority. Ranking results are summarized below.

Table 1. Research need ranking.

Ranking	Research need
1	Accelerated test procedures (lab and field). Self-reporting decay detection device
2	Molecular database for mapping and product failure; effect of soil and climate conditions on ground contact decay rate
3	Life cycle cost analysis (LCCA)
4	Resampling for verification of minimum retention
5	Water resistance across surfaces; moisture control with novel technologies
6	Environmental impact (soil/water and biological organisms)
7	Targeted wood preservatives
8	Fire performance and fire retardance of utility poles/urban interface
9	Stake test(s) of current preservatives
10	Durability, leachability, treatability of thermally modified wood
11	Fire and mold control on composites
12	Wood, moisture, conductivity under higher voltage
13	Treatment mechanics
14	Make high moisture wood more treatable
15	Treatability of refractory woods (emulsions, nanotechnology)

Collaborative Research Opportunities

Accelerated laboratory and field test method development has been a research emphasis for durability and wood protection researchers for more than two decades resulting in the development of numerous methods. Incipient decay detection (Clausen 1994), improved laboratory leach tests (Lebow in press; Lebow et al. 2008), miniaturized biochemical assays (Green et al. 1989), and biocide screening assays (Clausen and Yang 2011) are a few of the developments.

Accelerated aboveground and in-ground field test evaluations have been published and presented to the American Wood Protection Association. This research has clarified the relationship between specimen dimensions and time to failure, and the ability of short-term stake tests to predict long-term performance. However, it is recognized that more work is needed to understand how field test performance results correlate with service life.

Significant advances have been made in molecular analysis. It is a burgeoning field that provides the capability to map the changes in a field stake during decay and to create a database of decay fungi that can serve to map everything from incidence of tolerant fungi to ecosystem changes stemming from preservative prevalence at a test site to microbial progression during product failure. The number of potential research directions that molecular analysis might take is staggering, especially when considering newer platforms

that facilitate more robust (metagenomic) analysis of environmental samples. These newer technologies enable us to look at ecosystem level functions and interactions among not only fungi, but bacteria and other groups of microbes as well. The limiting factor will be funding and man-power since data can be generated many times faster than it can be processed. Collaborative efforts, both nationally and internationally, will improve the potential for funding, share the data-processing effort and provide a more complete database in a shorter period of time.

Fundamental research on the physiology of decay fungi and termites will help us develop control methods in concert with natural processes. Utilizing biochemical and genetic techniques, advances have been made in our understanding of key metabolic processes involved with fungal tolerance to chemical preservatives (Green and Clausen 2005; Hastrup et al. 2005; Jenkins et al. 2012). Understanding symbiotic relationships between termites and their normal flora may provide pathways for new approaches to control and lead to new microbial inhibitors. Scientists conducting fundamental research would be well-served to pool expertise and capabilities on these multi-faceted and complex issues.

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Appendix –Wood Protection Research Council Agenda



November 13, 2013

- 8:00-8:30 Registration
 8:30-8:40 Welcome and WPRC Objectives – Carol Clausen

Presentations

- 8:40 – 9:00 Predicting Field Performance – Stan Lebow, FPL
 9:00 – 9:20 Targeted Control of Termites and Decay Fungi – Rick Green, FPL
 9:20 – 9:40 Microbial Ecology of Biodeterioration – Grant Kirker, FPL
 9:40 – 10:00 Nano-Preservatives: Are they realistic? – Carol Clausen, FPL
 10:00 – 10:20 Break
 10:20 – 10:40 Environmental Life Cycle Assessments of Treated Wood – Jeff Miller, Treated Wood Council
 10:40 – 11:00 Testing Full Length Utility Poles – Kevin Ragon, Southern Pressure Treater’s Association
 11:20 – 11:40 BMP Verification and Treated Wood Guardrail Study – Dallin Brooks, Western Wood Preservers’ Institute
 11:40 – 12:00 Testing and Evaluating Creosote and Wood Crossties – Jim Gauntt, Executive Director of Railway Tie Association & Dave Webb, Creosote Council
 12:00 – 1:00 Lunch
 1:00 – 1:10 Treated Wood Products Standards – Colin McCown, Executive Vice President of AWPA

Roundtable Discussion

- 1:10 – 1:20 Objectives –Carol Clausen
 1:20 – 4:30 Roundtable discussion –Vicki Worden, facilitator
 4:30 – 5:00 Summary and closeout

