Environmental Performance of Treated Wood Cooperative

10th Annual Report

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Abbreviations

AWPA- American Wood Protection Association
ACQ- Ammoniacal Copper Quaternary
ACZA- Ammoniacal Copper Zinc Arsenate
BMPs- Best Management Practices
CA- Copper azole
CCA- Chromated copper arsenate
CuNap- Copper Naphthenate
DCOI- 4,5-dichloro-2-N-octyl-4-isothiazolin-3-one
EPA- United States Environmental Protection Agency
EPTW- Environmental Performance of Treated Wood Research Cooperative
PAH- Polycyclic Aromatic Hydrocarbon
TCLP- Toxicity Characteristic Leaching Protocol
UC- Use category
WWPI- Western Wood Preservers Institute

Executive Summary

Objective 1: Develop fundamental data on preservative migration from wood

a.) The Environmental Performance of Treated Wood Research Cooperative (EPTW) has performed extensive validation of voluntary post treatment Best Management Practices (BMPs) for treated wood to limit preservative migration from these products. This effort has examined the impact of BMPs on a variety of waterborne and oilborne preservative systems, but these do not include DCOI, a preservative slated to experience increased use in utility poles in the coming years. The EPTW is initiating a BMP verification effort for DCOI-treated Douglas-fir and southern pine using lumber pieces as a small-scale model system. Post treatment BMPs to be tested are steaming and post treatment vacuum.

b.) The EPTW has installed a field trial at the Oregon State University Lewis Brown Horticultural Farm to monitor the migration of metals from horticultural posts into vineyard soils and plant biomass. To date four different post treatments have been installed at the vineyard with 10 posts each, 5 with Postsaver wraps and 5 without. Treatments include CCA-treated Lodgepole pine, ACZA-treated Douglas-fir, CA-C-treated Douglas-fir peeler cores, and ACQ-treated Douglas-fir. One plant per post was installed 6 inches from each post with a drip irrigation line. Post retentions were measured and background metal levels in soils were measured this year. The first soil samples will be taken in January 2021 at the 6-month timepoint. Retention analysis indicates that three of the treatments used are below AWPA UC4A retention levels and treated posts with higher retention levels will be sought to add to this study in 2021.

c.) The EPTW initiated a sampling effort on an Oregon Tilth certified organic apple orchard which contains ACZA and CCA-treated posts that were present before certification. The purpose of the study was to determine whether treated posts caused any long-term impacts on metal levels in organic certified soils or produce in the orchard. The first sampling effort sampled 5 different posts within 3 feet of the base of an apple tree and 5 control trees at greater distances from treated posts. Analysis of copper, chromium and arsenic levels in soil, leaves, and apple samples taken from each showed that most samples had similar metal levels regardless of whether or not they were located near a treated post. Arsenic levels were elevated in soil samples taken 4 inches from the base of treated posts, but copper and chromium were not distinguishable from controls or soils farther away from the posts with 95% confidence. Elevated arsenic levels were not seen in soil samples taken from greater distances from the posts, indicating that increases were limited to within a small radius around the posts. Metal levels in the leaves and apples taken from control tress and trees near posts were indistinguishable. The first sampling showed high variability in metal levels within soil samples, indicating a larger sample size is needed to reduce variability. Further samples will be taken and analyzed in the summer and fall of 2021 prior to publication of the results.

d.) A field-scale soil leaching study was initiated to study the migration (if any) of polycyclic aromatic hydrocarbons (PAH) from creosote-treated posts at the Peavy Arboretum. Five southern pine and five Douglas-fir (6-7″ x 8′) creosote-treated posts were set 2′ in the ground at a level location at Peavy Arboretum. Soil samples were taken four inches from the base of the posts by excavating 18 inches of soil three months after installation (December 2020). The samples were divided into three 6-inch samples representing vertically distributed layers for later PAH extraction. The 16 priority pollutants monitored by the EPA will be measured in soil samples taken from the site. The goal of this project is to define leaching and migration rates for individual creosote components in soil. Results will be used to develop models for predicting creosote component migration in soils.

Objective 2: Develop standardized accelerated methodologies for assessing treated wood risks

The EPTW is developing a commodity scale leaching apparatus that can simulate a variety of leaching conditions representative of types of exposure conditions encountered by treated wood in the environment. The current prototype is loosely modeled off of leaching tests done by Dr. Kenneth Brooks but with a greater variety of functionalities built into the design. The leaching apparatus is designed to simulate multiple leaching conditions such as flow through, stagnant water, water recirculation, rain splash and overhead dripping. The leaching apparatus is a prototype and the methods require further development. We invite any commentary from members on how to improve this design.

Objective 3: Work cooperatively to develop and improve models to predict the risk of using treated wood in various applications

The EPTW website now hosts the Environmental Assessment Modeling Tool, following its update by Western Wood Preservers Institute (WWPI). The Environmental Assessment Tool was utilized to estimate the impact of damage to polyurea coatings on metal migration from CCA and ACZA-treated wood structures. The results of this analysis are summarized in an AWPA Proceedings article for 2020 (Citation in the section below). The EPTW has initiated a PAH migration study at the Peavy arboretum designed to monitor leaching from creosote-treated posts. The leaching apparatus described in objective 2 will also be used to generate more detailed predictive models based on a variety of leaching conditions representative of real-world exposure to water. The results of these and future studies will be used to develop soil migration models for PAHs which will expand OSU's modelling capacity to terrestrial environments.

Objective 4: Identify improved methods for reducing the potential for migration

As part of our study to monitor the migration of preservative chemicals into vineyard soils and plant tissue, half of all posts installed in this study have been installed with Postsaver wraps. As data are collected, these will be compared with uncovered posts and the analysis of this aspect of the vineyard migration project will be included in Objective 4.

Objective 5: Evaluate the environmental impacts and identify methods for reuse, recycling and/or disposal of preserved wood that is removed from service

The EPTW is participating in the Treated Wood Council's California Treated Wood Waste Subcommittee. The goal of this committee is to assess the accuracy of the California Department of Toxic Substances Control (DTSC) "hazardous" classification for treated wood. Additionally, the EPTW is planning a study to investigate hazardous waste testing protocols listed SW-846 that are required to test for hazardous waste by the DTSC. Among the methods used to classify hazardous waste is the EPA's toxicity characteristic leaching procedure (TCLP) summarized in method 1311. Leachability is determined by extracting 1 cm pieces of treated wood which is much smaller than most treated wood in landfills which primarily remains in larger pieces. Because of this discrepancy, real-world leachability of landfilled treated wood is likely much less than is determined by the TCLP. We will measure the impact of varying particle size in the TCLP on the final classification of various types of treated wood waste obtained locally and compare leachability results to leachability of full-sized treated wood commodities.

Objective 6: Deliver educational outreach programs on the proper use of treated wood in relation to BMPs

Based on a meeting with several Washington State departments, the EPTW will be undertaking a significant literature review in partnership with members of these departments. The review will cover the impacts of oilborne preservative-treated wood on the environment and will be made available to the Washington departments in the form of peer-reviewed minireviews and a comprehensive whitepaper consisting of the combined published sections. This effort was borne out of discussions with the Washington Departments around recent regulation restricting the use of oilborne preservatives in the State of Washington in some functions. The Washington departments based their decision in part on an aging whitepaper (published in 2001) and this effort will serve to update and expand on this document by publishing small research review papers on the environmental performance of oilborne preservatives. An outline of the topics that will be reviewed are included in the below report section. The EPTW is seeking input from members in the data collection phase of this effort to incorporate data on leaching and chemical discharge which may not be available in the peer reviewed literature.

Introduction

Treated wood is widely used in a variety of environments and has a well-known ability to markedly extend the service life of products, thereby reducing the need to harvest additional trees. The chemicals used to protect wood from degradation are toxic at some levels and all are known to migrate, to some extent, from the products treated with these chemicals into the surrounding environment. The concerns about this migration are highest in aquatic environments. Previous studies have shown that the levels of migration are generally low and predictable, and the Environmental Assessment Modeling Tool has been developed to predict the rates of migration from various treated wood commodities under a range of conditions. The treating industry also uses voluntary modified production procedures, Best Management Practices (BMPs), for some site-specific applications to improve the quality of these products, to reduce the presence of surface deposits, limit over-treatment, and, as far as practical, produce products with a reduced environmental footprint. The EPTW was established to help develop data on the performance of treated wood, beginning with aquatic applications. Extensive efforts were undertaken to validate best management practices for the prevention of preservative migration from treated wood and these continue today. The program is an extension of studies begun by Dr. Kenneth Brooks of Aquatic Environmental Sciences (Port Townsend, WA; Brooks 2011a).

Objectives

The overall goal of the EPTW is to develop knowledge that improves the ability to use and dispose of treated wood in a safe and environmentally sensitive manner. This goal is being addressed through the following objectives:

1. Develop fundamental data on preservative migration from wood
2. Develop standardized accelerated methodologies for assessing treated wood risks
3. Work cooperatively to develop and improve models to predict the risk of using treated wood in various applications
4. Identify improved methods for reducing the potential for migration
5. Evaluate the environmental impacts and identify methods for reuse, recycling and/or disposal of preserved wood that is removed from service
6. Deliver educational outreach programs on the proper use of treated wood in relation to BMPs

Over the past year, we have continued several efforts under some of these objectives, with involvement of the advisory committee. The results will be summarized by Objective.

Objective 1

Develop Fundamental Data on Preservative Migration from Wood

1.1.1 Evaluate the effects of best management practices on preservative migration patterns

The EPTW has undertaken an extensive effort to measure the impact of voluntary post-treatment Best Management Practices (BMPs) on the migration of chemicals from preservative-treated wood. Best management practices were originally developed in response to situations where freshly treated wood was transported to a site and then installed in projects where it was subjected to nearly immediate rainfall or soaking (WWPI, 2012). To simulate this scenario, tests were scaled down, using smaller pieces of treated wood that could be treated on-site at OSU and subjected to post-treatment BMPs immediately after treatment.

Characterization efforts have included several waterborne and oilborne preservative systems which were treated with one of several recommended BMPs for either oilborne or waterborne treatments. Previous efforts did not include 4,5-dichloro-2-n-octyl-isothiazolinone (DCOI), which is slated to gain market share as a utility pole preservative in the absence of pentachlorophenol. Therefore, post-treatment BMP validation will be done on DCOI-treated lumber to measure their impacts on DCOI leaching from wood.

The EPTW is initiating a study of the impacts of post treatment BMPs on DCOI leaching from treated lumber. The materials are currently being treated to UC4B retentions in diesel oil and will be ready for treatment with post-treatment BMPs in January, 2021. The BMPs to be tested are described below.

- **Post-treatment vacuum**: Samples will be subjected to a final vacuum (-75KPa) in the treating vessel after treatment for 1 hour.
- **Steaming:** Samples will be subjected to 1 or 2 hours of steaming at 100 °C with stickers between samples. Steaming will be performed in an autoclave where steam entering the vessel will be allowed to exit so that pressure remains near atmospheric.
- **Steaming and final vacuum:** Samples will be steamed in the treating cylinder at 100 °C for 1 or 2 hours prior to pulling a final vacuum (-75KPa) for one hour.

After BMP treatments, all samples will be stored frozen until leaching trials can be done. Each treatment will be replicated on one section cut from each board treated in this study to help reduce the potential for variability between boards.

Leaching tests

The potential for preservative migration will be evaluated in a specially constructed overhead leaching apparatus that applies a controlled amount of simulated rainfall at a desired temperature as described previously (M. Konkler et al., 2018; M J Konkler et al., 2020; Matthew J Konkler et al., 2020; Matthew J Konkler & Morrell, 2019; Simonsen et al., 2008; M Ye, 2013; Min Ye & Morrell, 2015a, 2015b)(Figure 1.1.1).

Figure 1.1.1 Overhead leaching apparatus used to evaluate the effects of BMPs on metal migration from preservative treated wood.

The apparatus (1.5 m wide x 0.6 m long x 0.9 m) was constructed with stainless steel and a plastic panel and had eight 152 mm wide x 457 mm long x 51 mm high sample holders. Holders were placed on a shelf with a 4.5° incline from the horizontal to allow water to flow down the wood. Simulated rainfall was produced by four spray nozzles connected to a deionized water supply. The rate of water spray was controlled by a small pump and an electronic controller. A pressure gauge near the spray nozzles also helps control flow.

BMP-treated DCOI samples will be placed into each holder and subjected to simulated overhead rainfall for 2 hours. Runoff will be collected in tared Erlenmeyer flasks that are weighed after rainfall exposure to determine the total volume of water applied per board for each time period. The weight of water will be recorded and 4.85 mL of each water sample placed into a vial. Water will be collected at 15-minute intervals for the first hour then at 30-minute intervals for the last hour.

Chemical analysis

DCOI retentions will be determined by solution uptake and x-ray fluorescence in treated lumber used in the leaching study. Runoff from samples treated with DCOI will be analyzed using HPLC according to AWPA A30 to determine DCOI concentration (AWPA, 2020). DCOI concentrations in water samples will be determined over the exposure period.

1.2.1 Minnesota field monitoring sites

In 2019, several bridge sites on the outskirts of Minneapolis, MN were sampled to identify whether metal or penta accumulation occurred in the environments surrounding the bridges over time. The structures are located in the town of Chaska, MN which has installed a number of bridges over the years, treated with either penta or CuNap. The first samples were taken in May of 2019 from 10 bridges. Five bridges were treated with penta and five were treated with CuNap. The first year's sampling data is summarized in the 2019 annual report.

Initially it was planned to revisit the site annually for several years, however travel restrictions related to the COVID-19 outbreak nationally prevented us from carrying out sampling in 2020. These sites will be returned to whenever possible after travel restrictions are lifted.

1.3.1 Effect of abrasion on metal levels in aquatic applications of treated wood

The EPTW has worked to evaluate the effects of various BMPs on subsequent migration of preservatives from treated wood. One subject that keeps arising is the contribution of surface abrasion. While wood is a reasonably abrasion-resistant material, repeated pedestrian or vehicle traffic can result in the loss of wood particles. These particles have very high surface to volume ratios that could potentially result in disproportionate preservative releases over time, especially in high traffic areas.

A field trial was established to assess the rate of wear on treated wood decking. Collecting fibers from bridges is problematic because they sluff off slowly and mix with the ground below, making them difficult to recover. Setting up fiber collection systems beneath a structure might be functional but instead, changes in conditioned mass of full-scale test samples installed on a bridge were selected as a measure of wear on the wood.

A trail bridge located in the McDonald-Dunn Research Forest of Oregon State University was selected for study. The bridge is located immediately adjacent to the Peavy Arboretum Starker Post Farm. It is heavily used by various school groups and visitors. The bridge is constructed using nominal 2 by 6 inch by 6-foot long Penta-treated decking and has been in place for at least a decade. The bridge crosses a seasonal wetland.

In the summer of 2018, copper azole treated DF lumber was purchased locally and cut to length. Samples were retained for later analysis, if needed. The lumber was conditioned to constant weight at 23 °C and 65% relative humidity before being weighed. The samples were then installed as replacement boards on the bridge (Figure 1.3.1). We expect that this project will take an extended period to show any measurable results, particularly because the boards must be weighed on a scale large enough to handle their size, which necessitates a loss in sensitivity. Because of this, the first sampling of this project will occur after a three-year period (2021) and weighed at three-year intervals after that, depending on the mass losses seen at the first sampling point.

Figure 1.3.1. Deck boards used to assess abrasion rates in the bridge at Peavy Arboretum.

1.4.1. Preservative migration from treated wood vineyard trellising with several different preservatives

Negative consumer sentiments around the presence of biocides in the agriculture sector has led an increasing number of fruit producers to choose alternative materials for their trellising systems. In addition, the growth of organic farming, which excludes treated wood in new construction entirely (USDA organic regulations; 7 CFR part 205), equates to a shrinking market share for treated wood products. Restrictions around using treated wood in organic agriculture are borne out of fears of contaminating soils and/or produce with metals leached from the treated wood. This is particularly true for arsenic-containing preservatives, which are the most commonly used for the manufacture of agricultural posts (The Beck Group 2020).

There have been only a few previous studies on the migration of preservatives from treated posts in vineyards. Study of arsenic migration from CCA-treated radiata pine posts into soils at a New Zealand Vineyard showed posts increase the soil concentration of copper, chromium and arsenic (Robinson et al., 2006). This study focused on soil very close to the treated posts, sampling a maximum of 5 cm away, and did not attempt to measure any impacts on nearby plants. Studies investigating preservative metal uptake into vines from treated wood posts in the field are rare and the limited work that has been done indicates there is no measurable impact of treated wood on vine metal content (Levi et al., 1975). Other studies of CCA-treated utility poles show that metal accumulation is limited to within 2 feet of the poles which makes it unlikely that large amounts of metal migrate from treated wood into grapevine biomass (Coles et al., 2014; Zagury et al., 2003). However, CCA is known to leach from treated wood, at distances that are modulated by the specific soil conditions of the area (Lebow et al., 2004). Therefore, treated wood impacts in agriculture are likely very site-specific, and we sought to study metal migration in the context of an Oregon vineyard.

The EPTW has initiated a field study at the Lewis Brown Horticultural farm at OSU to monitor the migration of metals from preservative-treated grapevine trellising. Trellising was installed in June-July 2020 and pinot noir grapes were planted shortly after the installation of the posts (Figure 1.4.1). Posts treated with four different preservative treatments were installed in the test site, ACQ Douglas-fir, ACZA Douglas-fir, CA-C Douglas-fir peeler cores and CCA lodgepole pine (Table 1.4.1). The posts were all nominally 3-4″ x 8′, although the ACZA-treated Douglas-fir were noticeably smaller than the other treatments. Ten posts from each treatment were installed, five with and five without Postsaver sleeves affixed to the posts 2′ from the post end. Four untreated and four steel posts were included in the trellis system as controls. Posts were installed 7-feet apart from one another and occupied two separate rows.

Figure 1.4.1: Photos of posts in grapevine trellising with a Postsaver sleeve (left) and the two rows of the completed grapevine trellis with plants at the base of posts (right).

One pinot noir grape plant was planted 6 inches from each post and drip irrigation lines were installed in each row with a drip head at each plant. Background soil samples were taken upon installation to determine background levels of metals in soils. Each post at the vineyard was cored at two locations for a total of 20 cores per treatment. Chemical retentions were determined with X-Ray fluorescence spectroscopy according to AWPA standard A9-18 and are listed in Table 1.4.1.

Table 1.4.1: Retention levels in posts installed in an experimental grapevine trellis at the Lewis Brown Farm

Preservative	Species	Target Retention kg/m^3 (pcf) UC4A	Retentions (posts in ground) kg/m^3	pcf
ACZA	Douglas-fir	6.4 (0.4)	3.70	0.23
CCA	Lodgepole pine	6.4 (0.4)	6.79	0.42
ACQ-B	Douglas-fir	6.4 (0.4)	1.93	0.12
CA-C	Douglas-fir peeler core	2.4 (0.15)	0.34	0.02

Soil samples were homogenized, oven dried, and microwave digested according to EPA method 3052. Briefly, 0.5 g of soil was placed into PTFE microwave extraction tubes and 10 mL of concentrated nitric acid was added. Samples were digested for approximately 9.5 minutes at 180 ℃ with a total microwave digestion time of about 15 minutes. The resulting digestate was rinsed from the tube with DI water and brought up to a volume of 25 mL with DI water and analyzed for appropriate metals by ICP-OES and expressed on a mg/kg basis. Ten mL of the extract was analyzed for metal concentration on an Agilent 5110 VDV ICP-OES at the Central Analytical lab at Oregon State University. The first sampling will be carried out in January 2021, 6 months after installation and will consist of taking soil cores four inches from the posts as deep as is possible and homogenizing prior to extraction for metal. Samples will be taken at 6-month intervals thereafter. As the plants mature, plant biomass will be sampled for metal accumulation. Leaf, vine and grape tissue will be harvested and extracted for metals as described above as they are produced by the vines. Metal content of soil and plant samples will be compared to control samples to determine whether any accumulation occurs over the course of this study.

1.5.1 Long-term metal accumulation in soils and plant biomass in a certified organic apple orchard in Oregon

The USDA organic regulations (7 CFR part 205) state that treated wood is not permitted to be utilized new or replacement installations on certified organic farms. However, organic certification does not require the removal of existing structures provided it is not in direct contact with crops (NOP 5036, 2018). This is also the case for state-certification programs such as Oregon Tilth (https://tilth.org/help-center/treated-wood/). Because of this, many organic farms actually utilize treated wood for trellising despite prohibitions on its use in new construction. This situation ensures that in some cases treated wood can stay in service on organic farms for the decades-long lifespan of the treated wood. This raises the question: Does treated wood contaminate soil, plants or produce in certified organic agriculture? To answer this, the EPTW sought to identify cases where treated wood is used in organic agriculture to measure whether treated wood has an impact on organic soil, plant matter, or produce.

The EPTW identified an Oregon Tilth certified organic apple orchard at the Oregon State University Lewis Brown Horticultural farm which contains treated posts as part of an aging trellising system (Figure 1.5.1). The orchard was planted c.a. 1996 as a conventional apple orchard which utilized treated posts in its trellising system. In 2010 the orchard was certifed organic by Oregon Tilth and the treated posts remained in place and they are still in service today.

Figure 1.5.1: Photo of the Oregon Tilth Certified Organic apple orchard at the Lewis Brown Horticultural Farm

A sampling effort was initiated in the summer and fall of 2020 to measure metal levels in orchard soils, leaves and apples in close proximity to posts as compared to controls much farther away from posts (Figure 1.5.2). This assessment was done to identify any long-term impacts on metal levels in orchard soils, plant biomass or fruit produced in the orchard resulting from the treated wood present in the orchard. The initial sampling in 2020 included soil, leaves and apples taken from five posts within three feet of the base of an apple tree. Control trees were selected throughout the orchard in areas that were at least 15 feet from the nearest posts. Based on previous studies of poles treated with arsenicals, metal levels in soil surrounding poles drop to levels similar to background within a 2-foot distance from the pole surface, indicating that the control trees selected should not have any impact from other posts in the orchard (Coles et al., 2014; Zagury et al., 2003).

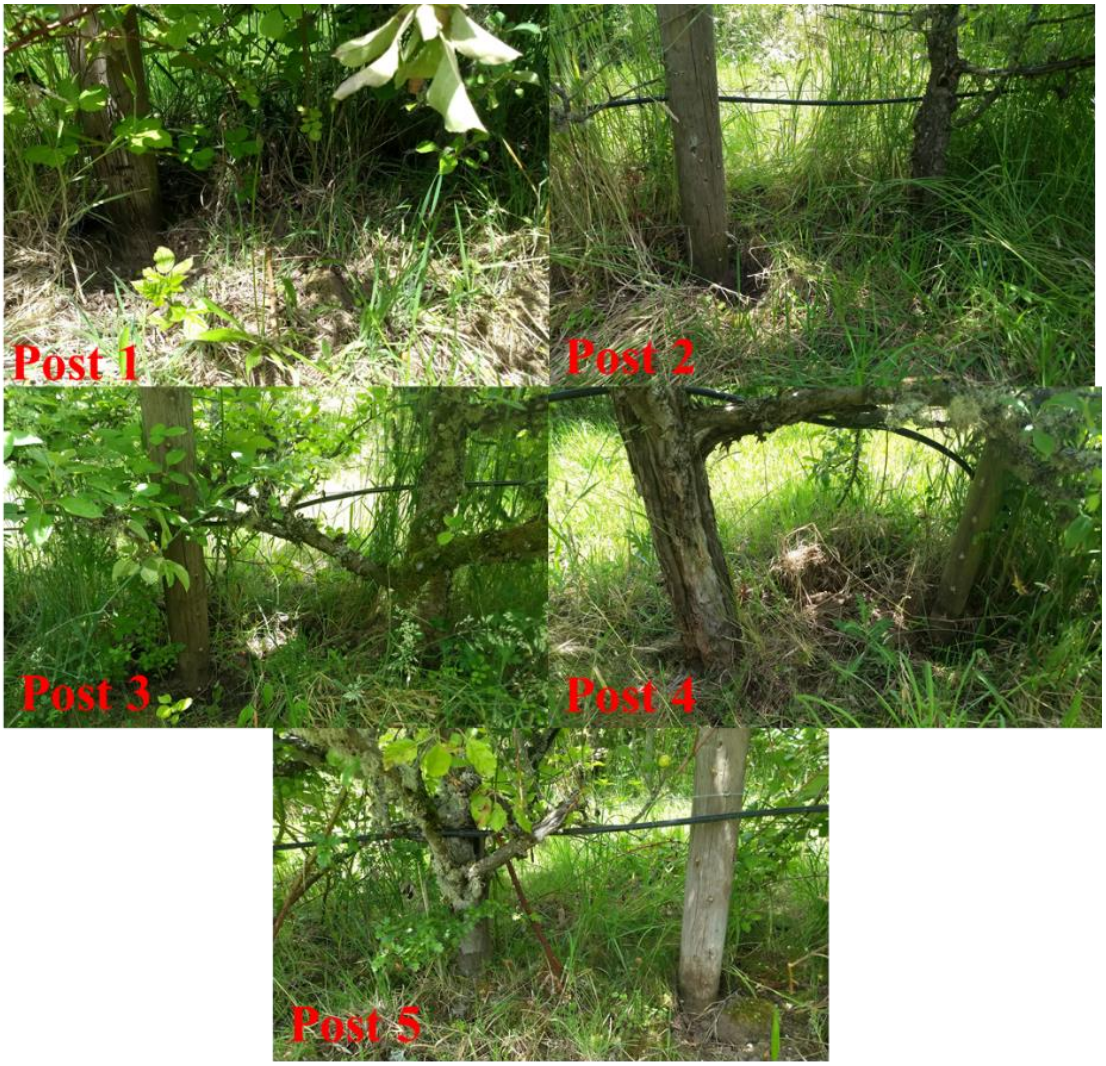

Figure 1.5.2 Five Treated posts near apple trees that were sampled in this study.

Five posts selected for sampling were cored at 8 locations ranging from 0.15 m underground to 1.2 m above ground. Cores were pooled and the assay zone was isolated for each prior to measuring metal concentration by X-Ray fluorescence spectroscopy according to AWPA standard A9-18. The preservative treatment was unknown for these posts so a scanning protocol was done for each of the five posts. It was found that four of the five posts contained zinc, arsenic and copper but only background levels of chromium indicating that they were treated with ACZA. One post contained no zinc and contained copper, chromium and arsenic, indicating it was treated with CCA. Retentions for the posts selected for this study are listed in Table 1.5.1. Horticultural posts in this region are typically treated to UC4A retentions (6.4 kg/m^3/0.4 pcf) and the posts in this study contain 45-133% of the UC4A target level after about 25 years of service.

Table 1.5.1: Preservative retention levels in posts sampled at the Lewis Brown Farm certified organic orchard.

Post #	Preservative	Total Retention CCA/ACZA kg/m^3 (pcf)	UC4A retention kg/m^3 (pcf)	% remaining of UC4A
Post 4	CCA	8.6 (0.54)	6.4 (0.4)	133.9
Post 1	ACZA	3.2 (0.2)	6.4 (0.4)	49.6
Post 2	ACZA	2.9 (0.18)	6.4 (0.4)	45.0
Post 3	ACZA	5.6 (0.35)	6.4 (0.4)	87.5
Post 5	ACZA	3.6 (0.22)	6.4 (0.4)	56.1

Leaves were sampled from trees randomly at different locations around the tree crown not obviously in contact with the neighboring post. Leaves were sampled in the spring and the fall and the metal levels were averaged across these timepoints. Apples were sampled when they were available, which for one control and one post tree was in the spring and fall sampling points and the remaining apple samples were taken only in the fall sampling point. Soil samples were taken only at the spring timepoint and were extracted by pounding a soil corer into soil four inches from the base of control trees and trees near posts and extracting a soil core extending about 6 inches deep. Soil samples were also taken 4 inches from the base of posts. Soil samples were homogenized prior to sampling. Samples were oven dried and ~0.5 g of soil and/or 0.2 g of biomass was extracted according to EPA method 3052 as described in section 1.4.1. Total metal content of the extract was calculated, was normalized to the mass of soil extracted and presented as ppm (mg/kg).

Copper, chromium and arsenic levels in leaf and apple tissue taken from trees near posts were indistinguishable from tissue sampled from control posts (Figure 1.5.3). Metal levels for all three metals were all below 8 ppm in leaf samples (Table 1.5.2). Copper levels in one of three technical replicates taken from leaves near one of the posts was ~4 times higher than the other two technical replicates, leading to the high variance in this sample. It is unknown why this occurred, but potentially indicates high within sample vairability. Leaf sampling was done randomly by picking leaves from a random selection of leaves around the tree canopy. This may indicate that leaves at different locations on the tree have different copper exposure, although in this sampling no leaves were obviously in contact with treated posts when they were sampled. Average metal levels in apples were all below 3 ppm (Table 1.5.2). Most apples were sampled in the fall and all of these had metal levels below detection limit (counted as 0 ppm here). The only apples with detectable metal levels were harvested in the summer months before they were fully ripe. Metal levels in control leaves and apples were not statistically significantly different than their counterparts taken from near posts ($p>>0.05$) (Table 1.5.3).

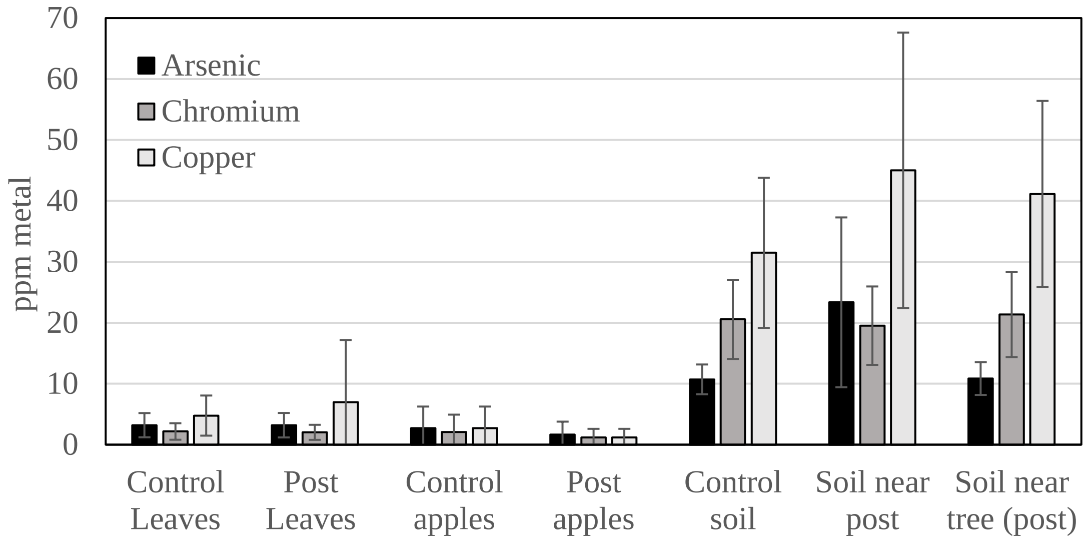

Figure 1.5.3: Arsenic copper and chromium levels in soil, leaves and apples taken from or near trees near treated posts or control trees far away from posts.

Table 1.5.2: Metal concentration of orchard soil, leaves and apples taken from near posts and control trees far away from treated posts.

	Average ppm metal*		
Sample	As	Cr	Cu
Control Leaves	3.2 (2.0)	2.2 (1.4)	4.8 (3.3)
Post Leaves	3.2 (2.0)	2.0 (1.2)	7.0 (10.2)
Control apples	2.7 (3.6)	2.1 (2.8)	2.7 (3.6)
Post apples	1.7 (2.1)	1.2 (1.4)	1.2 (1.4)
Control soil	10.7 (2.4)	20.6 (6.5)	31.5 (12.3)
Soil near post	23.3 (13.9)	19.5 (6.4)	45.0 (22.6)
Soil near tree (post)	10.8 (2.7)	21.4 (7.0)	41.1 (15.3)

*Numbers in parentheses are one standard deviation

Table 1.5.3: p values calculated from statistical comparison of control samples to samples near treated wood using ANOVA and a Tukey's HSD test.

		Tukey's HSD p value*		
Group 1	Group 2	Arsenic	Chromium	Copper
Control leaf	Post leaf	1.000000	1.000000	0.998018
Control apple	Post apple	0.999918	0.999806	0.999991
Control soil	Post soil near tree	1.000000	0.999187	0.375346
Control soil	Post soil near post	0.000001	0.996431	0.066393
Post soil near tree	Post soil near post	0.000002	0.934016	0.981172

*A p value <0.05 indicates the mean values are significantly different with 95% confidence.

Soil samples taken from near control trees contained an average of 10.7 ppm As, 20.6 ppm Cr and 31.5 ppm Cu. Soil samples near treated posts contained an average 23.3 ppm As, 19.5 ppm Cr and 45.0 ppm Cu indicating arsenic levels were elevated by about two-fold compared to controls ($p<<0.05$, Tukey's HSD). Copper levels also appeared elevated in the soil taken near treated posts compared to control soils, however elevation of copper levels was not significant with 95% confidence ($p = 0.066$) (Table 1.5.2; Table 1.5.3). Soil samples taken from the base of trees near posts contained similar metal levels to control posts and these were not statistically different, indicating arsenic likely did not accumulate above background levels much farther than a 4-inch radius from the treated posts.

There was a high degree of variability in metal levels among soil samples and even among technical replicates of the same sample. This is particularly evident in arsenic levels from soils taken 4 inches from the treated posts, where some metal levels taken from one of the ACZA-treated posts varied by a factor of 4 between different technical replicates (Table 1.5.4). This high in-sample variability makes it difficult to resolve differences among the different sample types with confidence and is not unexpected with such a small sample size (five per sample type) of soil, which is a highly variable material. Further sampling efforts will be undertaken in the late summer of 2021 to add to the sample size before publishing this data.

The metal levels measured here are similar to or less than levels found in previous studies around posts in agricultural applications. For example, Robinson et al. 2006 measured arsenic levels in soils 50 mm (~2 inches) away from vineyard posts which were below 50 ppm on average for posts that are only a few years old. Levels found 4 inches from posts in this study were about half of those found in Robinson et al. 2006. This may be due to the greater distance away from the posts or the advanced age of posts in this study which provided time for metal content of soils to dissipate via further migration. The lower arsenic levels found in this study after ~25 years of service in the apple orchard may be a result of leaching stabilizing over time, stopping accumulation sometime during the life of the post. Preservative retentions in the orchard posts show significant amounts of metals remain in posts indicating that there is a risk for further leaching. However previous work shows that accumulation of metals in soils is not necessarily related to the preservative retention levels in wood (Lebow et al. 2004). In addition, most leaching occurs in the early stages of treated wood exposure to water whereafter metal migration dissipates (M Ye, 2013). Leaching from posts ~25 years old should have stabilized barring any damage to them.

Table 1.5.4 Metal concentration (all replicates) in samples taken from the organic apple orchard in this study.

			ppm (kg/g) metal[1]			
Sample	Sample date	Replicate #	As	Cr	Cu	Zn[2]
Control 1 leaf	5/28/2020	1	6.3	4.5	9.9	

Control 1 leaf	5/28/2020	2	4.5	2.7	8.1	
Control 1 leaf	5/28/2020	3	4.5	2.7	7.2	
Control 1 leaf	9/30/2020	1	0.0	0.0	0.0	0.0
Control 2 leaf	5/28/2020	1	4.5	3.6	7.2	
Control 2 leaf	5/28/2020	2	3.6	2.7	5.4	
Control 2 leaf	5/28/2020	3	4.5	2.7	8.1	
Control 2 leaf	9/30/2020	1	0.0	0.0	0.0	0.0
Control 3 leaf	5/28/2020	1	3.6	2.7	3.6	
Control 3 leaf	5/28/2020	2	4.5	2.7	7.2	
Control 3 leaf	5/28/2020	3	4.5	2.7	5.4	
Control 3 leaf	9/30/2020	1	0.0	0.0	0.0	0.0
Control 4 leaf	5/28/2020	1	3.6	2.7	5.4	
Control 4 leaf	5/28/2020	2	3.6	2.7	6.3	
Control 4 leaf	5/28/2020	3	3.6	2.7	9.0	
Control 4 leaf	9/30/2020	1	0.0	0.0	0.0	0.0
Control 5 leaf	5/28/2020	1	3.6	2.7	5.4	
Control 5 leaf	5/28/2020	2	4.5	2.7	3.6	
Control 5 leaf	5/28/2020	3	4.5	2.7	3.6	
Control 5 leaf	9/30/2020	1	0.0	0.0	0.0	0.0
Post 1 leaf	5/28/2020	1	4.5	3.6	7.2	
Post 1 leaf	5/28/2020	2	4.5	2.7	4.5	
Post 1 leaf	5/28/2020	3	2.7	2.7	46.8	
Post 1 leaf	9/30/2020	1	0.0	0.0	0.0	0.0
Post 2 leaf	5/28/2020	1	4.5	2.7	10.8	
Post 2 leaf	5/28/2020	2	2.7	2.7	9.0	
Post 2 leaf	5/28/2020	3	4.5	2.7	9.0	
Post 2 leaf	9/30/2020	1	0.0	0.0	0.0	0.0
Post 3 leaf	5/28/2020	1	4.5	2.7	6.3	
Post 3 leaf	5/28/2020	2	4.5	2.7	5.4	
Post 3 leaf	5/28/2020	3	3.6	2.7	2.7	
Post 3 leaf	9/30/2020	1	0.0	0.0	0.0	0.0
Post 4 leaf	5/28/2020	1	5.4	1.8	4.5	
Post 4 leaf	5/28/2020	2	3.6	2.7	1.8	
Post 4 leaf	5/28/2020	3	4.5	2.7	14.4	
Post 4 leaf	9/30/2020	1	0.0	0.0	0.0	0.0
Post 5 leaf	5/28/2020	1	5.4	2.7	6.3	
Post 5 leaf	5/28/2020	2	4.5	2.7	7.2	
Post 5 leaf	5/28/2020	3	4.5	2.7	3.6	
Post 5 leaf	9/30/2020	1	0.0	0.0	0.0	0.0
Control 1 apple	5/28/2020	1	9.0	7.2	9.0	
Control 1 apple	5/28/2020	2	3.6	2.7	3.6	
Control 1 apple	5/28/2020	3	3.6	2.7	3.6	
Control 1 apple	9/30/2020	1	0.0	0.0	0.0	0.0
Control 4 apple	9/30/2020	1	0.0	0.0	0.0	0.0
Control 5 apple	9/30/2020	1	0.0	0.0	0.0	0.0

Post 1 apple	5/28/2020	1	4.5	2.7	2.7	
Post 1 apple	5/28/2020	2	3.6	2.7	2.7	
Post 1 apple	5/28/2020	3	3.6	2.7	2.7	
Post 1 apple	9/30/2020	1	0.0	0.0	0.0	0.0
Post 2 apple	9/30/2020	1	0.0	0.0	0.0	0.0
Post 4 apple	9/30/2020	1	0.0	0.0	0.0	0.0
Post 5 apple	9/30/2020	1	0.0	0.0	0.0	0.0
Control 1 soil	5/28/2020	1	8.9	19.7	57.2	
Control 1 soil	5/28/2020	2	7.2	9.0	16.2	
Control 1 soil	5/28/2020	3	9.0	18.1	50.6	
Control 2 soil	5/28/2020	1	8.8	12.4	15.9	
Control 2 soil	5/28/2020	2	10.8	21.6	30.6	
Control 2 soil	5/28/2020	3	10.7	25.1	37.6	
Control 3 soil	5/28/2020	1	12.6	23.3	34.1	
Control 3 soil	5/28/2020	2	10.8	28.8	36.1	
Control 3 soil	5/28/2020	3	9.1	21.8	30.9	
Control 4 soil	5/28/2020	1	18.2	18.2	23.7	
Control 4 soil	5/28/2020	2	10.9	9.1	10.9	
Control 4 soil	5/28/2020	3	10.9	20.0	27.3	
Control 5 soil	5/28/2020	1	10.9	23.6	29.1	
Control 5 soil	5/28/2020	2	10.8	28.7	34.1	
Control 5 soil	5/28/2020	3	10.9	29.0	38.0	
Post 1 soil near post	5/28/2020	1	60.4	23.1	95.9	
Post 1 soil near post	5/28/2020	2	50.7	23.5	76.1	
Post 1 soil near post	5/28/2020	3	16.2	7.2	16.2	
Post 2 soil near post	5/28/2020	1	17.7	14.1	37.1	
Post 2 soil near post	5/28/2020	2	30.9	25.5	67.3	
Post 2 soil near post	5/28/2020	3	19.8	21.7	50.5	
Post 3 soil near post	5/28/2020	1	24.8	24.8	60.3	
Post 3 soil near post	5/28/2020	2	14.2	8.9	21.3	
Post 3 soil near post	5/28/2020	3	18.1	12.7	32.6	
Post 4 soil near post	5/28/2020	1	12.7	16.4	23.6	
Post 4 soil near post	5/28/2020	2	16.0	26.7	44.5	
Post 4 soil near post	5/28/2020	3	16.1	25.0	41.0	
Post 5 soil near post	5/28/2020	1	20.0	16.3	18.1	
Post 5 soil near post	5/28/2020	2	16.2	21.6	41.5	
Post 5 soil near post	5/28/2020	3	16.3	25.4	49.0	
Post 1 soil near tree	5/28/2020	1	12.8	23.7	56.6	
Post 1 soil near tree	5/28/2020	2	9.0	25.1	55.5	
Post 1 soil near tree	5/28/2020	3	10.6	23.0	53.1	
Post 2 soil near tree	5/28/2020	1	17.7	31.9	47.9	
Post 2 soil near tree	5/28/2020	2	9.1	27.2	47.2	
Post 2 soil near tree	5/28/2020	3	9.0	9.0	16.2	
Post 3 soil near tree	5/28/2020	1	10.7	23.2	37.4	
Post 3 soil near tree	5/28/2020	2	9.0	7.2	9.0	

Post 3 soil near tree	5/28/2020	3	9.0	19.8	30.5
Post 4 soil near tree	5/28/2020	1	8.9	24.8	49.7
Post 4 soil near tree	5/28/2020	2	10.7	24.9	48.0
Post 4 soil near tree	5/28/2020	3	9.1	23.6	41.7
Post 5 soil near tree	5/28/2020	1	10.6	10.6	23.0
Post 5 soil near tree	5/28/2020	2	10.8	21.5	41.3
Post 5 soil near tree	5/28/2020	3	15.9	24.8	60.1

[1] A value of zero equates to below detection limit
[2] Four metal analysis was only run for samples taken in the fall

1.6.1 Monitoring the migration of polyaromatic hydrocarbons in soil from creosote-treated Douglas-fir and southern pine posts

Creosote is a widely used wood preservative for heavy duty applications including critical infrastructure such as utility poles, railroad ties, and marine pilings (Webb, 2014). It has a long history of effective use and is the oldest wood preservative originating from the industrial age (Rhodes, 1951). Creosote contains a variety of PAHs that provide it with fungicidal activity and several of these are on the Environmental Protection Agency's (EPA) priority pollutant list and are regulated by the EPA (Nestler 1974; 40 CFR Part 423, Appendix A). PAH migration from creosote treated wood has been extensively studied, particularly in aquatic environments (Brooks 2011b). These and other data have led to the environmental assessment modelling tool hosted on the EPTW website, which helps predict the impact of treated wood on preservative levels in water bodies.

Aquatic environments are not the only environment creosote is utilized in and it is often utilized in terrestrial applications where migration risk is into soil rather than water. The understanding of PAH migration from treated wood in soils is less well understood than aquatic environments and we do not possess the capacity to model leaching from creosote-treated wood in contact with soils. One of the most common applications for creosote on land is for the treatment of railroad ties. Creosote leaching from railroad ties into the surrounding ballast and soils has been studied previously showing minor vertical migration and statistically insignificant migration into surrounding wetlands (Brooks 2004). However, the available leaching data for terrestrial systems is limited compared to that which has been generated for aquatic exposure of creosote treated wood.

PAH migration through a system as complex as a ballast with multiple strata and material types would be difficult to model and initial efforts to produce a predictive modelling tool for terrestrial systems should focus on simpler terrestrial systems. The EPTW initiated a study to measure rates of PAH migration from creosote-treated posts at the Peavy Arboretum with the aim of incorporating this data into a terrestrial migration model. Data will be collected for all 16 PAHs in creosote that are on the EPAs priority pollutant list.

A total of ten 6-7″x 8′ creosote-treated posts, 5 Douglas-fir and 5 southern pine, were installed at the Peavy Arboretum field site in August 2020 (Figure 1.6.1). Posts were installed 2 feet in the ground in a level area of the field site. Two untreated Douglas-fir posts were installed as controls and background soils samples were taken upon installation. Soil samples were taken three months after installation (December 2020) and will be taken 6 months after installation and at 6-month intervals thereafter until the completion of the study. At the three-month sampling point soil samples were taken 4 inches away from the posts only as it was expected that not much migration had occurred at this time. Soil cores were taken down to an 18-inch depth and the soil cores were divided into three 6-inch sections representing different soil horizons. The full 24-inch depth of the underground portion of the post could not be sampled because the clay consistency of the soil inhibited obtaining a deep soil sample. Subsequent samples will be taken at 4 inches away from the posts and if PAHs are detected at the 4-inch sample, a second distance will be introduced that will attempt to delineate the PAH plume beyond the 4-inch sampling point. Soil density, organic matter content and cation exchange capacity will be measured as well.

Figure 1.6.1: Photos of the creosote-treated Douglas-fir and southern pine posts at the Peavy Arboretum

Soil samples were extracted and analyzed for PAHs using methods described previously (Forsberg et al., 2011). Briefly; soil samples were homogenized and 10 g subsamples were weighed into centrifuge tubes. Twenty mL of a 2:2:1 acetone:ethyl acetate:iso-octane mixture was added to the centrifuge tubes. The tubes were sonicated for 5 minutes to ensure that sediment was in intimate contact with solvent. The samples were then treated with a salt mixture containing 6 g of magnesium sulfate and 1.5 g of sodium acetate. The mixture was again sonicated for 5 minutes and then centrifuged for 5 minutes. A 1.5 mL aliquot of supernatant was removed and added to a 2 mL dispersive solid-phase micro-extraction tube (SPME) and sonicated further for 5 minutes. These dual procedures were used to precipitate polar compounds, lipids, fatty acids, sterols and other compounds that could interfere with analyses. Tubes were then centrifuged again for 5 minutes and a 1 mL aliquot of the supernatant was removed for and analyzed for EPAs 16 PAH priority pollutants on a Shimadzu GC-MS (Anastassiades et al., 2003; Forsberg et al., 2011; Martinez et al., 2004).

Samples were analyzed using a Shimadzu QP2010S GC-MS operated in scan mode, mz range 50-300, with a splitless injection. One µL of sample was injected and analyses were performed with the following conditions: Oven temperature: 70 °C held for 2 minutes then increased to 265 at 10 °C a min. and held at 265 °C for 15.5 min until Benzo(ghi)perylene eluted (total run time 37 minutes), ion source temperature: 225 °C, interface temperature: 275 °C, injection temperature 275 °C. The samples were analyzed on an RXI-5ms column (0.25 mm inner diameter by 30 mm long) at a flow rate of 2.5 mL/min.

The first samples were taken three months after installation in December 2020 and are currently being processed. The next sampling will occur in February 2021. Soil and/or sediment concentration of each PAH will be measured in ppm and migration rates will be measured in mg PAH/kg soil/month.

Objective 2

Develop Standardized Accelerated Methodologies for Assessing Treated Wood Risks

2.1.0 Development of a commodity scale leaching apparatus for controlled experiments

The EPTW is developing a commodity scale leaching apparatus that can simulate a variety of leaching conditions representative of types of exposure conditions encountered by treated wood in the environment. The current prototype is loosely modeled off of leaching tests done by Dr. Kenneth Brooks but with a greater variety of functionalities built into the design. The leaching apparatus is designed to simulate multiple leaching conditions such as flow through, stagnant water, water recirculation, rain splash and overhead dripping.

The leaching apparatus consists of a 15-gallon cone-bottom tank with a Tee fitting leading to two ball valves (Figure 2.1.1). One valve empties out the container so leach water can be sampled during the test while the other valve leads to a water pump that allows recirculation into the leaching tank (Figure 2.1.2). The pump can also be rerouted to a clean water source so fresh water can be pumped into the tank or sprayed onto the piece of treated wood for a flow-through leaching experiment. The tank was partially filled with smooth decorative river stones to serve as an inert support for a polyurea-coated ACZA-treated post for demonstration purposes. The rocks were large enough to allow drainage of the tank for recirculation or sampling. Sprinkler fittings can be attached to hoses to change the water application method to simulate rain splash (sprinkler head) or water dripping on pilings from decking (irrigation tubing). We will continue to modify the apparatus to develop standard leaching protocols to simulate different types of environmental exposure.

The leaching apparatus is in a prototype form currently and the methods require further development. We invite any commentary from members on how to improve this design.

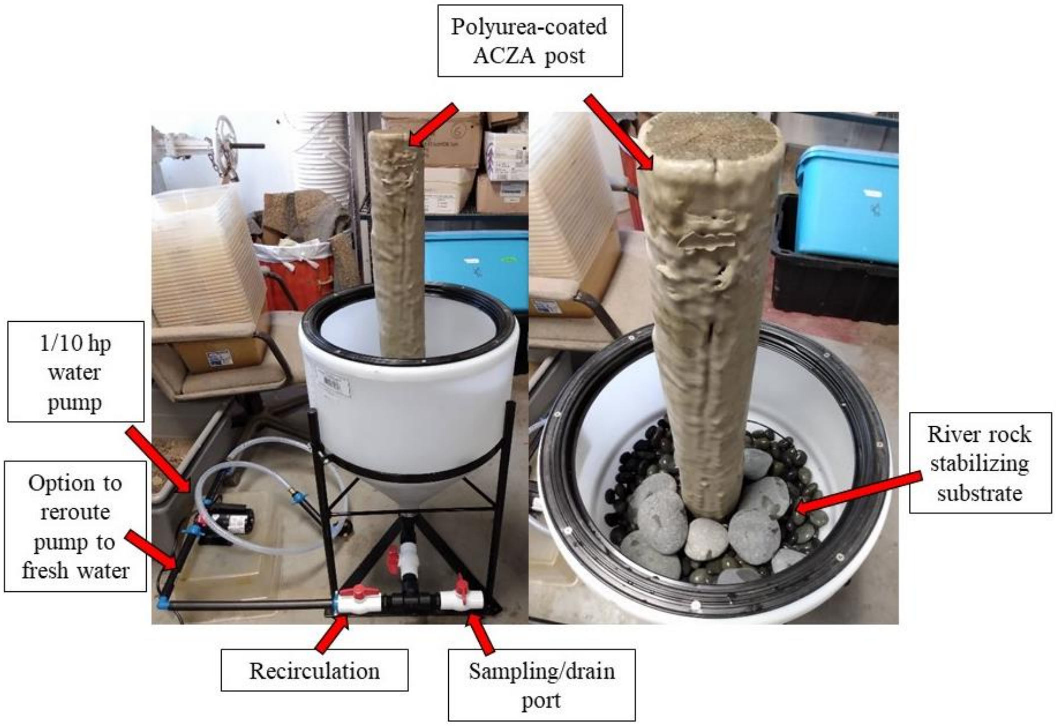

Figure 2.1.1: Prototype leaching apparatus with a coated piece of treated wood in it for demonstration. A front view of the leaching apparatus is shown on the left and a top down view is shown on the right.

Figure 2.1.2: Demonstration of recirculation function of the prototype leaching apparatus (left) and drip leaching functionality (right). Further modifications will need to be made to run this apparatus in a test.

Objective 3

Work Cooperatively to Develop and Improve Models to Predict the Risk of Using Treated Wood in Various Applications

The EPTW has initiated a field study to investigate the migration of creosote in soils at the Peavy Arboretum. This study is part of an effort to collect high resolution data on the migration of EPA's 16 priority pollutants from creosote-treated wood in ground contact. These data will be used with future studies to inform predictive models for PAH migration from treated wood into soils.

The EPTW is developing a lab-based leaching test designed to measure leaching rates under various controlled conditions that simulate real-world exposure. Quantitative tests done with the apparatus can be used to help improve treated wood leaching models over time.

The Environmental Assessment Tool was utilized to estimate the impact of damage to polyurea coatings on metal migration from CCA and ACZA-treated wood structures. The results of this analysis are summarized in an AWPA Proceedings article for 2020 and will be made available through the AWPA website. The information for this submission is shown below.

Konkler, M. J., Presley, G., and Morrell, J. J. (2020). Effect of damage to polyurea coatings on metal migration from CCA and ACZA treated wood: use of the aquatic risk model. American Wood Protection Association Proceedings, 116: 136-145

Objective 4

Identify Improved Methods for Reducing the Potential for Migration

As part of our study to monitor the migration of preservative chemicals into plant tissue, we have included Postsaver sleeves in this study to determine if barriers below groundline reduce the migration of preservatives into soil and plant tissue. As data from that study is generated, the impact of including Postsaver sleeves will be included in this section.

Objective 5

Evaluate the Environmental Impacts and Identify Methods for Reuse, Recycling, and/or Disposal of Preserved Wood that is Removed from Service

The EPTW is participating in the Treated Wood Council's California Treated Wood Waste Subcommittee. The goal of this committee is to assess the accuracy of the California Department of Toxic Substances Control (DTSC) "hazardous" classification for treated wood. One of the factors behind DTSC's policy is a 2008 report assessing wood waste treated with CA, ACQ, or creosote where most samples were determined to be hazardous wastes according to California regulations (Snider 2008). The report describes hazardous waste characterization according to several EPA and DTSC standard procedures.

DTSC requires hazardous waste testing facilities to utilize EPA standard hazardous waste testing protocols (SW-846) to classify hazardous waste. Standard extraction methods required by DTSC include the Toxicity Characteristic Leaching Procedure TCLP (EPA method 1311) which specifies that wood particles fit through a 1 cm sieve before they are extracted. However, in practice, treated wood disposed in a landfill primarily exists as pieces larger than the TCLP test size. This indicates that chemical leaching from treated wood waste in landfills is likely much less than predicted by the TCLP protocol.

We are planning a study to measure the effect of treated wood particle size on its classification as a hazardous waste according to extraction procedures outlined in the TCLP. We've obtained several pieces of treated wood waste locally including creosote-treated railroad ties, ACZA and penta-treated timbers and pole sections. More examples of treated wood waste will also be collected for this study.

We will measure the impact of varying particle size in protocols listed in SW-846 on the final leachability measurements of treated wood waste. Total chemical content must also be measured as part of the hazardous waste classification. Continued efforts in this area could lead to the development of an index for treated wood commodity leachability based on total chemical content and commodity size rather than leachability of 1 cm particles as determined by the TCLP.

Objective 6

Deliver Educational Outreach Programs on the Proper Use of Treated Wood in Relation to the Best Management Practices (BMPs)

6.1.1 Review of the existing literature describing the environmental impacts of oilborne preservative systems

In January 2020, the EPTW traveled to Olympia, WA for a meeting with WWPI and representatives from several Washington State departments on the regulatory status of oil borne preservatives in that state. We utilized the WWPI environmental assessment modelling tool to help educate the attendees about environmental risk mitigation for preservative treated wood structures. As a result of this meeting the EPTW will be reviewing the environmental impacts of oilborne preservatives and publishing this information in a series of peer reviewed mini reviews and as a single, unpublished source made available to the Washington departments and EPTW members. This effort will serve in part to update a whitepaper from 2001 used by the Washington departments to inform policy through the publication of a series of peer-reviewed publications. The review will include current research on oilborne preservatives occurring since 2001 and any other information on the environmental performance of oilborne-treated wood available from EPTW members. An outline of topics to be included in this literature review effort is shown below as an outline.

Assessment of environmental impacts of oil-borne wood preservatives and future research needs

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I. Introduction

Oil borne preservatives are widely used in the preservation of wood in industrial applications and they have a long history of effective use dating back to the use of creosote in the late 18th and early 19th century. Today, oilborne preservatives are essential treatments for the preservation of large timbers for industrial applications such as railroad ties, utility poles, marine pilings and bridges. Wood preservatives by their nature are biocidal and contain chemicals that can cause harm to biological systems. While the majority of the chemical loaded into treated wood remains in the wood itself, some inevitably leaches from the treated wood over time into the surrounding environment. The minimization of preservative migration is essential for the safety of the environments treated wood is used in and the integrity of the treated product. Lower preservative migration equates to less environmental contamination and more active ingredient retained in the wood to ensure long-term performance. Therefore, it is in the interest of both regulatory bodies, the public and treated wood manufacturers to minimize the migration of chemicals from treated wood into the environment. This review will summarize the environmental impacts of oil borne preservatives, methods of risk mitigation and gaps in the understanding of the environmental performance of these preservative systems.

II. Why treated wood?

Wood is a biological material and, like all biological materials, has an inherent susceptibility to decomposition. Because of this, wood must be treated with preservatives to maintain its structural integrity while exposed in the environment. This is in contrast to other structural materials such as steel and concrete which are non-biodegradable and do not require chemical treatment for resistance to biological decay. However, wood possesses a variety of properties that make it an attractive building material for critical infrastructure. Wood is a renewable resource sourced from rural areas around the United States and its production sustains rural economies in wood-producing region. Because wood is a plant-based material derived from CO_2 fixation, its use does not result in excess carbon emissions and functions as a carbon sink. Preservatives make wood products last longer and prevent the return of carbon bound in wood to the atmosphere long enough for replacement wood to grow, making wood treatment an essential factor contributing to wood's sustainability. This is in contrast to steel and concrete which are extremely carbon-intensive materials to manufacture and rely on limited, mined and extracted resources to produce. That said, wood is an excellent industrial building material for our time that can help mitigate the impacts of global climate change and stimulate rural revitalization.

III. Oil borne preservative systems
  a. Creosote
    i. Description, manufacture, uses (include environments where used)
    ii. Chemical composition, Types
    iii. Historical comparison creosote today versus older structures
    iv. Current distribution of creosote products in WA
  b. Pentachlorophenol
    i. Description, manufacture, uses (include environments where used)
    ii. Current distribution of penta products in WA
    iii. The status of Penta production in North America and future prospects
  c. Copper Naphthenate
    i. Description, manufacture, uses (include environments where used)
    ii. Current distribution of CuNap products in WA
    iii. Prospects for CuNap as a penta replacement
  d. 4,5-dichloro-2-n-octyl-4-isothiazolin-3-one (DCOI)
    i. Description, manufacture, uses (include environments where used)
    ii. Current distribution of DCOI products in WA
    iii. Prospects for DCOI as a penta replacement
  e. Solvent systems used for oilborne treatments
    i. Comparison of current and historical formulas
    ii. Pairings of solvent and preservative systems

IV. Chemical migration of oil-borne preservatives from treated wood
  a. Creosote-PAHs
    i. Controlled lab studies
    ii. Sources of PAHs in the environment
    iii. Field monitoring
      1. Note environmental data for available studies
    iv. Detection methods
  b. Pentachlorophenol
    i. Controlled lab studies
    ii. Field monitoring
      1. Note environmental data for available studies
    iii. Detection methods
  c. Copper Naphthenate
    i. Controlled lab studies
    ii. Field monitoring
      1. Note environmental data for available studies
    iii. Detection methods
  d. DCOI
    i. Controlled lab studies
    ii. Field monitoring
      1. Note environmental data for available studies

- iii. Detection methods
- e. Solvent migration from treated wood

V. Impacts of preservative migration on terrestrial ecosystems
- a. Creosote
  - i. PAHs impact on human health
  - ii. PAHs effects on plants and algae
  - iii. PAH toxicity to megafauna
- b. Pentachlorophenol
  - i. Penta impacts on human health
  - ii. Penta effects on plants and algae
  - iii. Penta toxicity to megafauna
- c. Copper Naphthenate
  - i. Penta impacts on human health
  - ii. Copper effects on plants and algae
  - iii. Copper toxicity to megafauna
- d. DCOI
  - i. DCOI impacts on human health
  - ii. DCOI effects on plants and algae
  - iii. DCOI toxicity to megafauna
- e. Synergistic effects of combined preservative chemicals on terrestrial life

VI. Impacts of preservatives on aquatic ecosystems
- a. Creosote
  - i. PAHs impacts on Aquatic invertebrates
  - ii. PAHs impacts on fish
  - iii. PAHs phytotoxicity
- b. Pentachlorophenol
  - i. Penta impacts on aquatic invertebrates
  - ii. Penta impacts on fish
  - iii. Penta phytotoxicity
- c. Copper Naphthenate
  - i. Copper impacts on Aquatic invertebrates
  - ii. Copper impacts on fish
  - iii. Copper phytotoxicity
- d. DCOI
  - i. DCOI impacts on Aquatic invertebrates
  - ii. DCOI impacts on Fish
  - iii. DCOI phytotoxicity
- e. Synergistic effects of combined preservative chemicals on aquatic life

VII. Environmental fate of leached preservatives
- a. Creosote
  - i. Background PAHs in environmental samples
  - ii. Minimum effects thresholds

        iii. Microbial metabolism of PAHs
        iv. UV degradation
        v. Persistent PAHs
    b. Pentachlorophenol
        i. Minimum effects threshold
        ii. UV degradation
        iii. Dioxin and pentacholoranisole accumulation and persistence
    c. Copper Naphthenate
        i. Copper naphthenate as a source of copper
        ii. Minimum effects threshold
        iii. Copper bioaccumulation
        iv. Copper sedimentation
        v. Dilution
    d. DCOI
        i. Minimum effects threshold
        ii. Biodegradation
    e. Solvent systems fate in the environment

VIII. Risk mitigation measures for oil-borne preservative treated wood
    a. Best management practices
    b. Special precautions for sensitive environments
    c. Building practices
    d. Environmental modeling

IX. Gaps in the understanding of preservative migration and environmental impacts

Literature Cited

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