Assessment of polycyclic aromatic hydrocarbons (PAHs) migration from creosote-treated Douglas-fir and southern pine posts over a 38-month period

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Abstract: Creosote is a widely used industrial wood preservative largely used for infrastructure-related applications such as utility poles, railway ties, and marine pilings. Polycyclic aromatic hydrocarbons (PAHs) are the predominant component, and some PAHs in creosote have been identified by the Environmental Protection Agency (EPA) as priority pollutants. While research on PAHs found in aquatic environments is widespread, studies on terrestrial PAH migration from creosote-treated wood commodities are less common. This study sought to quantify the extent (quantity, distance, and depth in soil column) of PAH migration from creosote-treated wood in ground contact by measuring the concentration of 16 EPA-regulated PAHs in soil around creosote-treated Douglas-fir and southern pine posts over a 38-month period. The concentrations of PAHs were highly variable from chemical to chemical and timepoint to timepoint, but a few trends were discernible. Where differences were apparent between the two wood species, soils around southern pine posts tended to have higher PAH concentration than soils around Douglas-fir posts, likely due to the differences in chemical retention in the outer 25 mm of the wood, at 143 kg/m^3 and 52 kg/m^3, respectively. Lighter PAHs, particularly naphthalene and acenaphthene, were often found in controls. This indicates that some of the lighter PAHs likely originated from a combination of environmental inputs such as wildfire smoke and vehicle emissions in addition to creosote. Distance from the post surface also played a role in determining PAH concentration for several PAHs. Several higher molecular weight PAHs (fluoranthene, pyrene, benz [a] anthracene, chrysene, benzo [a] pyrene and others) were more frequently identified in samples taken 15 cm from the post than in samples taken 30 cm from the posts in the later sampling times. This field study is ongoing and will continue to examine PAH migration from creosote-treated commodities.

Keywords: Wood preservative; Soil; Ground contact.

Introduction

Creosote is a widely used industrial wood preservative for protecting utility poles, marine pilings, railroad ties, and other commodities against fungi, insects, and marine borers. Creosote has seen historically wide usage as an effective wood preservative since its patent was filed by Franz Moll, a German chemist in 1836, and its subsequent inception in the United States in 1865 (Webster 1992). In 1952, approximately 227 million gallons of creosote and creosote solutions were used in the United States (Baechler and Stamm 1954), though that number has declined more recently, with North American industry estimates totaling around 82.9 million gallons of all creosote formulations used in 2007 (Vlosky 2009).

Chemically, coal tar creosote is formed from the destructive distillation (pyrolysis) of bituminous coal. This process, commonly known as coking, is the process of heating coal at elevated temperatures to form a high-carbon form of coal

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ultimately used to smelt steel. The viscous byproduct formed from coking, creosote, is a variable and complex mixture of hundreds of chemicals, including polycyclic aromatic hydrocarbons or PAHs (up to 85% of mass), phenolic compounds (10% of mass), and heterocyclic aromatic compounds (5% of mass) (Mueller et al. 1989; Nestler 1974). An analysis of creosote used in a former commercial wood treatment facility also detected up to 1505 individual compounds and 231 additional derivatized compounds (Gallacher et al. 2017).

As the largest constituent of creosote, PAHs are a structurally related class of compounds globally and are not specific to creosote as a wood preservative. Processes that include the partial and inefficient combustion of organic matter, such as forest fires, release PAHs in smoke (Navarro et al. 2019; O'Malley et al. 2024), and anthropogenic sources such as the burning of fossil fuels (Wilson and Jones 1993) act as a release of PAHs into the environment. Some PAHs are either known, probable, or suspected carcinogens that have also been shown to negatively impact the function of various organisms in different ecosystems (Eisler 1987) such as fish and other aquatic invertebrates (Duncan et al. 2017; Gewurtz et al. 2000). Because of the potentially toxic characteristics of some PAHs, 16 PAHs ranging from two to six fused aromatic rings are classified and regulated as priority pollutants by the US Environmental Protection Agency (EPA) under the Clean Water Act (US EPA 1981). Because many of these PAHs have several possible sources in the environment, quantifying the relative contribution of creosote-treated commodities is important in quantifying their environmental impact.

Historically, creosote-treated pilings were widespread, and prior literature regarding the environmental performance of creosote is somewhat limited to that of aquatic environments (Bestari et al. 1998; Brooks 2004; Kang et al. 2005; Murphy and Brown 2005; Shupe et al. 2006). While some studies have shown limited impacts of creosote on aquatic life living on or around creosote-treated pilings, today new construction using creosote pilings is limited, and terrestrial applications are more widespread (Goyette and Brooks 1998). Terrestrial applications commonly used include railroad crossties/sleepers and utility poles, with 98% of railway ties in the US having been treated with creosote or creosote solution (RTA 2025).

Prior work to quantify PAH migration from railroad ties shows that increases in PAH from creosote railroad ties in wetland sediments were detectable up to at least 0.75 m away from an experimental railroad ballast (Brooks 2004). Total PAH losses were small, however, and resulted in only about a 0.3 µg/g increase in total PAH concentration in neighboring wetland sediment and fell well below any thresholds expected to negatively impact biological systems. At the end of their service life, it is estimated that 65% of the creosote remains in the treated railway tie (Bolin and Smith 2013). Railroad ballasts suspending the treated ties have a buffering effect for treated commodities, and creosote-treated wood found in direct ground contact may represent a greater environmental risk.

Several studies have examined PAH migration from creosote-treated railroad ties or utility poles in service or in storage. Cargouët et al. (2018) found that the maximum sum of all measured PAH concentrations in soil derived from old creosote-treated railway ties in storage ranged from 2 mg/kg up to 140 mg/kg on a dry weight basis, but decreased dramatically within a few centimeters from the railway ties in storage. Similarly, a study on PAHs found in soil and olives near derelict creosote-treated railroad ties ranged from around 115 to 2160 µg/kg in total for light PAHs up to 1 m from the railway tie, but measured PAH concentration decreased dramatically with distance (Moret et al. 2007). Later work also showed that PAH migration from creosote-treated utility poles was limited to about a 20-cm radius around each pole (Brooks 2020). However, the number of direct studies on PAH migration from wood in ground contact remains relatively limited. Further study of PAH migration from creosote-treated wood in a service-replicated scenario can help disentangle its impact from that of other environmental pollutants.

In this study, the migration of 16 PAHs classified as EPA Priority Pollutants and constituents of creosote-treated Douglas-fir and southern pine posts was examined at a field test site near Corvallis, Oregon over a 38-mo period. The data presented in this study provides data on the species- and time-dependent migration pattern(s) of 16 PAHs at different distances from the treated wood surface and depths within the soil column.

Experimental methods

Acquisition and analysis of creosote-treated posts

In this study, five coastal Douglas-fir (*Pseudotsuga menziesii*) and five southern pine posts 15–20 cm in diameter and 2.4 m long were treated with a P1/P13 creosote fraction at commercial facilities in Oregon (Douglas-fir) and in the southeastern United States (southern pine). Posts were stored under cover prior to installation at the field site. Creosote retention levels in the outer 0–25 mm of the posts were assayed according to the AWPA A6 standard method for the determination of retention of oil-type preservatives from small samples (AWPA



Figure 1. Photo of field test setup showing southern pine and Douglas-fir posts set below ground in soil at Peavy Arboretum. Untreated control posts were located above creosote-treated posts along the gradual hillside to prevent downslope migration of PAHs in the soil column from creosote-treated posts.

2020) as an aggregate sample for all posts included in the test. Creosote-treated Douglas-fir posts contained 52 kg/m^3 creosote and southern pine posts contained 143 kg/m^3 creosote in the outer 25 mm assay zone.

Experimental design

A field-scale migration study was performed at the Peavy Arboretum about 10 km north of Corvallis, Oregon (Figure 1). The field site is located in a maritime climate with average daily high temperatures ranging from 7.7°C in January to 28.3°C in August. Annual rainfall at the site is about 1084 mm, with the majority falling from October to May. Soil at the Peavy Arboretum field site was subjected to a full soil panel at the Soil Health Laboratory at Oregon State University, Corvallis. Results of the physical and chemical analyses are shown in Table 1. The soil is a clay texture and is rich in organic matter, with relatively high microbial respiration rates.

Creosote-treated posts were placed 0.6 m below groundline at the Peavy Arboretum field site. In addition, two untreated Douglas-fir posts were used as controls. Soil taken from the hole dug for each post was analyzed for the presence of 16 PAHs found in creosote, and these were labeled as 0-mo samples for each post. Soil samples were taken using a 2.5 × 61 cm (1.0 × 24-in.) stainless steel soil corer to obtain 46 cm (18-in.) soil cores. Soil cores were taken with the center of the soil sampler centered at each sampling distance. Soil sampling times included 0-mo (background), 3-mo, 6-mo, 12-mo, and 38-mo after post installation. For each sampling period, the soil cores were taken at a different part of the radius around the post to reduce disturbances between samplings.

Table 1. Soil characteristics at the Peavy Arboretum field test site, Corvallis, Oregon.

Characteristic	Quantity
% Moisture	9
% Sand	22
% Silt	34
% Clay	44
% Water stable aggregates	99
% C	13.28
% N	0.6
% Organic matter	26.56
Active carbon (ppm)	1073.44
CO_2 respiration 24 h (µg CO_2-C/g dry soil/day)	273.85
CO_2 respiration 96 h (µg CO_2-C/g dry soil/day)	131.63
Potentially mineralizable nitrogen (ppm NO_3-N time 0)	1.77
Potentially mineralizable nitrogen (ppm NO_3-N time 28)	4.01
Potentially mineralizable nitrogen (mg N/kg soil/day)	0.08
pH	5.61
P (ppm)	29.81
K (ppm)	233.24
Ca (ppm)	6235.49
Mg (ppm)	1152.82
Cation exchange capacity (meq/100g)	41.38

For the background (0-mo) samples, soil was collected from soil augured out of the ground to set the post. For the 3- and 6-mo sampling point, soil was sampled 15 cm from the treated post. For the 12- and 38-mo sampling points, soil samples were taken at two distances, 15 and 30 cm from the treated post. The total 46 cm (18 in.) long soil cores were divided into three 15-cm (6 in.) sections, an upper 0–15 cm, middle 15–30 cm, and lower 30–46 cm section (Figure 2). The 46 cm (18 in.) soil cores were difficult to obtain intact so they could be reliably sectioned into 15 cm sections, and the sampling method required some distance from the post to maneuver the soil corer. This limited the closest distance to 15 cm from the outside surface of the post. The 30 cm sampling distance was added to help identify distance-dependent trends in PAH accumulation in soil around creosote-treated roundwood.

Each soil section (upper, middle, or lower) was homogenized and retained for PAH extraction. The soil coring apparatus was cleaned of all soil between each core taken by wiping off excess soil, rinsing the coring apparatus with water while cleaning it with a brush, and finally spraying it down with ethanol and wiping it to dry. All soil samples taken in this study were frozen until extracted for 16-PAHs, as described in the section below.

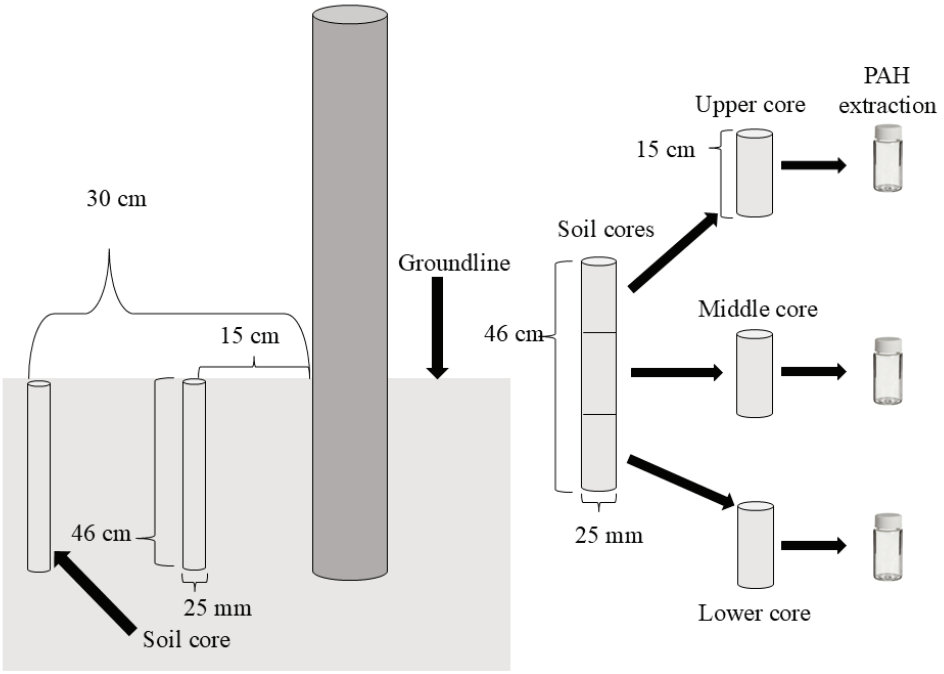


Figure 2. Diagram of soil sampling regime and division of complete soil sampling core into three respective segments below the groundline.

PAH soil extraction procedure

Triplicate 10 g subsamples of each soil sample were extracted and analyzed for PAH content. Soil samples were not dried prior to extraction to help retain volatile PAHs, and they were not ground sieved or otherwise fractionated before extraction. Each 10 g subsample was placed into a pre-weighed 50 mL Falcon tube. Twenty mL of a 2:2:1 acetone: ethyl acetate: isooctane (v/v) mixture was added to each Falcon tube and weighed again. The samples were hand shaken to remove any sediment stuck to the bottom of the tube then sonicated for 5 min. The samples were then treated with a single QuEChERS packet consisting of a salt mixture containing 6 g of magnesium sulfate and 1.5 g of sodium acetate (Agilent Technologies, Santa Clara, CA). After the addition of the QuEChERS packet, the tubes were weighed (after drying the tubes after the initial sonication) and sonicated for another 5 min, followed by 5 min of centrifugation at 5,000 RPM.

All supernatants were transferred to a pre-weighed 20 mL amber glass scintillation vial and weighed to determine solvent recovery on a weight basis. Samples were then concentrated under a gentle stream of house air for approximately 15 min and weighed again. A 1.5 mL aliquot was then transferred to a 2 mL dispersive solid phase extraction (SPE) microcentrifuge tube and sonicated for 5 min. The SPE tube was then centrifuged for 5 min at 5,000 RPM and a final 1 mL aliquot of supernatant was transferred to an amber autosampler vial and frozen until GC-MS analysis. The remaining supernatant in scintillation vials was retained and frozen, should future analysis be necessary.

GC-MS Analysis

Sixteen different PAHs were quantified in each extract using GC-MS. All standards and samples were analyzed using a Shimadzu GCMS-QP2010S GC-MS (Shimadzu, Kyoto, Japan) utilizing selective ion monitoring (SIM) and a Restek DB-5MS column 30.0 m long, 0.25 µmm thick, and 0.25 mm internal diameter (Restek Corp. Bellefonte, PA). Instrument injection was operated in spitless mode with a 3.5 mm glass liner with de-activated glass wool. A 1 µL injection was performed at 275°C. Chromatography of the 16 PAHs of interest was attained at a column flow rate of 2.50 mL/min using HP-5 grade ultra-high purity helium as the carrier gas. Column oven temperature was set to 70°C, held for 2 min, increased to 265°C at a rate of 10.0K/min, and held for 18.5 min for a total run time of 40 min. Mass spectrometer ion source and interface temperature were 225°C and 275°C, respectively, with a solvent cut time of 5 min. If no signal was detected using GC-MS, a value of zero was assigned to the PAH concentration in the extract, and these were included in the calculation of average values shown below.

Calibration curves were generated by preparing standards from a 2000 µg/mL 16-PAH reference standard from Sigma Aldrich (St. Louis, Missouri) in dichloromethane. Concentration of

Table 2. The 16 polycyclic aromatic hydrocarbons (PAHs) measured in this study, with quantification limits for the GC-MS method used. Concentrations are listed for extracts of soil.

PAH name	Quantification limit on instrument (µg/ml)
Naphthalene	0.010
Acenaphthylene	0.010
Acenaphthene	0.010
Fluorene	0.010
Phenanthrene	0.025
Anthracene	0.025
Fluoranthene	0.010
Pyrene	0.010
Benz[a]anthracene	0.075
Chrysene	0.075
Benzo[b]fluoranthene & Benzo[k]fluoranthene	0.025
Benzo[a]pyrene	0.050
Indeno[1,2,3-cd]pyrene	0.100
Benzo[g,h,i]perylene	0.050
Dibenz[a,h]anthracene	0.100

PAH standards prepared from the 2000 µg/mL stock solution were 0.005, 0.01, 0.1, 0.5, and 1.0 µg/mL. Quantification limits based on the lowest reliably detectable standard for each PAH in extracts varied, ranging from 0.01 to 0.1 µg/ml, and are shown in Table 2.

Results and discussion

Concentrations of PAH found in soils around the creosote-treated posts varied widely among the 16 different PAHs of interest, sampling locations, and sampling times. Discernible patterns were sometimes but not always present across these variables for each PAH. PAH concentrations in soil were often highly variable, which made average PAH levels around creosote-treated wood difficult to differentiate statistically from those found around controls at each timepoint. Particularly for the heavier PAHs, frequency of detection among replicate samples was a more useful indicator of relative abundance. In the interest of brevity, 4 of the 16 PAHs are discussed below, which span most of the molecular weight range of the 16 PAHs in the study. These are naphthalene, acenaphthene, chrysene, and benzo [a] pyrene. Concentrations of all 16 PAHs in soil samples analyzed in this study over the 38-mo study period can be found in supplemental Tables S1–S5.

Naphthalene

Naphthalene was found at the highest levels in the background samples taken before installation and in the non-treated control sample 30 cm from the outer surface of the post at 15–30 cm deep in the soil (Figure 3). This suggests that at the time of installation, soils likely had acquired some naphthalene from sources other than creosote. As the field site is in an area that experiences seasonal wildfires, naphthalene could have been deposited from wildfire smoke. Wildfire smoke is a known source of PAHs and their alkylated derivatives in the environment, such as naphthalene, 2-methyl naphthalene, phenanthrene, and retene (Navarro et al. 2019; O'Malley et al. 2024). Naphthalene is also a component of vehicle exhaust, and the initial impulse of naphthalene could have come from the skid steer used to install the posts (Baimatova et al. 2017).

Average naphthalene concentrations in soil trended higher in the 3-mo sampling than in the 6-mo timepoint at all sampling locations (Figure 3). This could be a result of a lingering effect of the 2020 wildfire season at the field site, which was exceptionally intense. Naphthalene in the gaseous phase may have been deposited into the soil in 2020 wildfire smoke and since dissipated over time, either through volatilization (Kim et al. 2011) or biodegradation. Average concentrations of naphthalene found 12- to 38-mo after installation all trended lower than the initial 3- to 6-mo period at all heights and distances from the post surface and were generally identical, with no evident trend of elevated naphthalene concentrations through time.

Naphthalene concentrations in samples taken around controls in the initial 6 mo were similar to those of samples taken around creosote-treated posts, except for the 3-mo sampling, where they were somewhat lower than in samples taken around treated posts. From the 12-mo period onward, average concentrations of naphthalene in controls were consistently lower, apart from the 38-mo timepoint, at 30 cm from the post surface, whereas concentrations in the middle 15–30 cm sample were similar to background control concentrations found prior to installation. This suggests that if creosote is contributing to overall naphthalene concentrations in soils, it does so in an impulse of naphthalene migration within the initial months following installation, and migration remains consistent. This is in line with previous observations of creosote-treated wood exposed to simulated rainfall, where the highest PAH losses resulted from the first volumes of rainfall exposure (Konkler et al. 2020). No obvious trends were present in naphthalene concentrations at the different soil depths and distances.

Another factor that may have contributed to higher naphthalene concentrations at the 3- and 6-mo sampling points is seasonality. The site where this study was performed receives most of its rainfall in the winter months, where soil temperatures

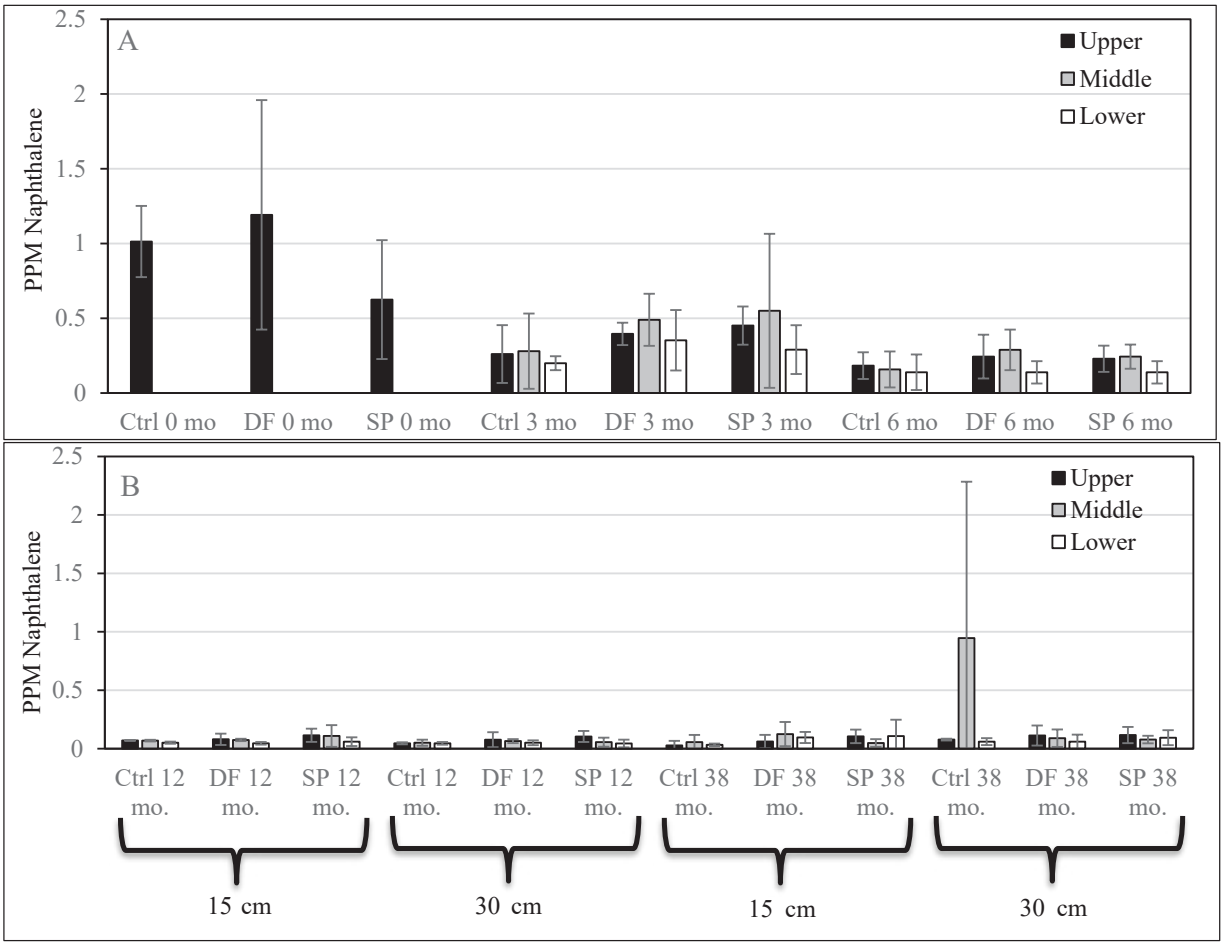


Figure 3. Average naphthalene concentrations (ppm, wet weight basis) found in soils around creosote-treated Douglas-fir (DF) and southern pine (SP) posts at (A) 0–6 mo, 15 cm from the post surface; and (B) 12–38 mo after installation, 15 and 30 cm from the post surface. Soil was sampled at three depths in the soil column: 0–15 cm (upper), 15–30 cm (middle), and 30–46 cm (lower). Error bars are plus or minus one standard deviation.

are lowest as well. The 3- and 6-mo samplings were done in December and March, respectively. The combination of high levels of water runoff and lower microbial metabolism rates of naphthalene in the cooler soils (Coulon et al. 2005) may have contributed to higher naphthalene recovery in these sampling points, as opposed to the 12- and 38-mo sampling points, which occurred in warmer and drier parts of the year.

Acenaphthene

Acenaphthene concentrations in soils were generally lower in the early months of the study compared to naphthalene (Figure 4). Average acenaphthene concentrations 30 cm from the control posts at the 38-mo sampling point were elevated in the middle 15–30 cm soil sample due to high levels around one of the replicate controls, similar to the pattern seen with naphthalene. This suggests that the site has some environmental source or pre-existing acenaphthene that is not attributable to creosote. Trends in acenaphthene migration also differed from naphthalene in that the 12-mo sampling point around southern pine posts showed similar or higher concentrations to the 3-mo sampling point, indicating that PAH migration is either continuing from the posts in the later timepoint or did not dissipate from the initial impulse coming from the treated wood. Samples taken from around southern pine treated posts 15 cm from the post surface had average acenaphthene concentrations that trended higher than levels found in samples taken 30 cm from the post surface. This trend was not as clear around pine posts in soils sampled 38 mo after installation, but a few replicate samples had relatively higher acenaphthene levels at the closer 15-cm sampling point than the 30-cm sampling point around Douglas-fir posts. Overall, the spatial differences were small and acenaphthene levels had a lot of overlap across sampling locations for each post type.

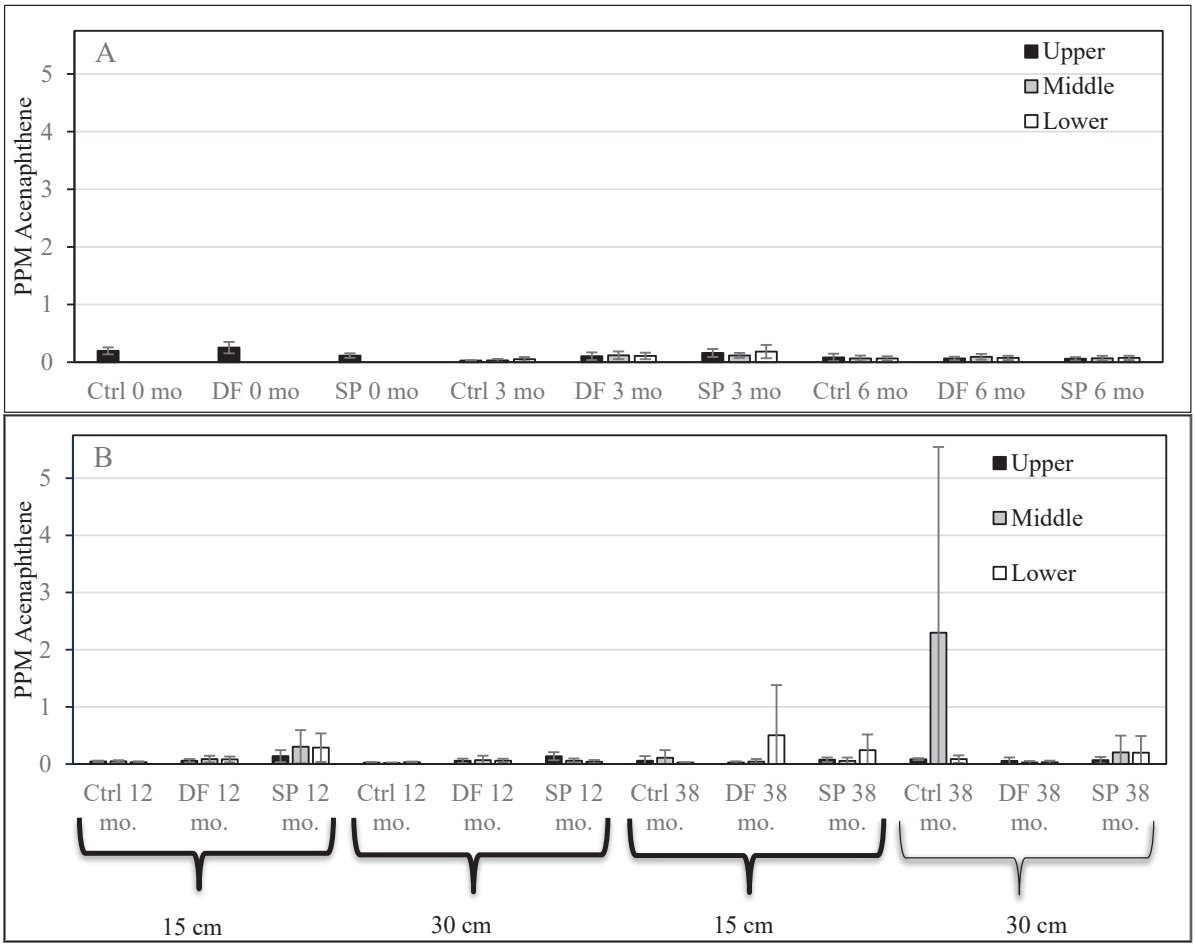


Figure 4. Average acenaphthene concentrations found in soils around creosote-treated Douglas-fir and southern pine posts at (A) 0–6 mo, 15 cm from the post surface; and (B) 12–38 mo after installation, 15 and 30 cm from the post surface. Soil was sampled at three depths in the soil column: 0–15 cm (upper), 15–30 cm (middle), and 30–46 cm (lower). Error bars are plus or minus one standard deviation.

Chrysene

Heavier PAHs such as chrysene (Figure 5) showed a different pattern of migration compared to naphthalene and acenaphthene. Average chrysene levels in background samples were generally similar to those found in controls throughout the sampling period in the first 12 mo. Average chrysene levels in controls remained near the detection limit for replicate samples in the first 12 mo. It was more common to detect chrysene in the samples taken around treated posts in most cases, which resulted in higher average chrysene levels, although levels were very similar around controls and untreated posts in the first 12 mo. Increases of the average chrysene concentration in both Douglas-fir and southern pine posts post 15 cm from the surface were apparent after 38-mo. Average concentrations in southern pine posts 38 mo after installation 15 cm from the post were somewhat sporadic, but higher than Douglas-fir posts, ranging from around 2.0 to 6 ppm. Average concentrations 30 cm from the post in both species trended lower, but similarly, higher average concentrations were found in southern pine posts ranging from around 0.2 ppm to 1.8 ppm. Higher average concentrations found around southern pine posts are perhaps evidence of the higher creosote retention in treated southern pine posts than in Douglas-fir, at 143 kg/m^3 and 52 kg/m^3, respectively, in the 25 mm assay zone.

Benzo [a] pyrene

Another heavy PAH, five ring benzo [a] pyrene (Figure 6) showed a similar migration pattern as chrysene, except that overall average concentrations in soil were generally lower, crossing 0.05 ppm in only two sampling locations/times in treated posts within the first 12 mo of the study. Benzo [a] pyrene was not found 30 cm from the post surfaces, except in one instance, around Douglas-fir posts in the initial 12-mo

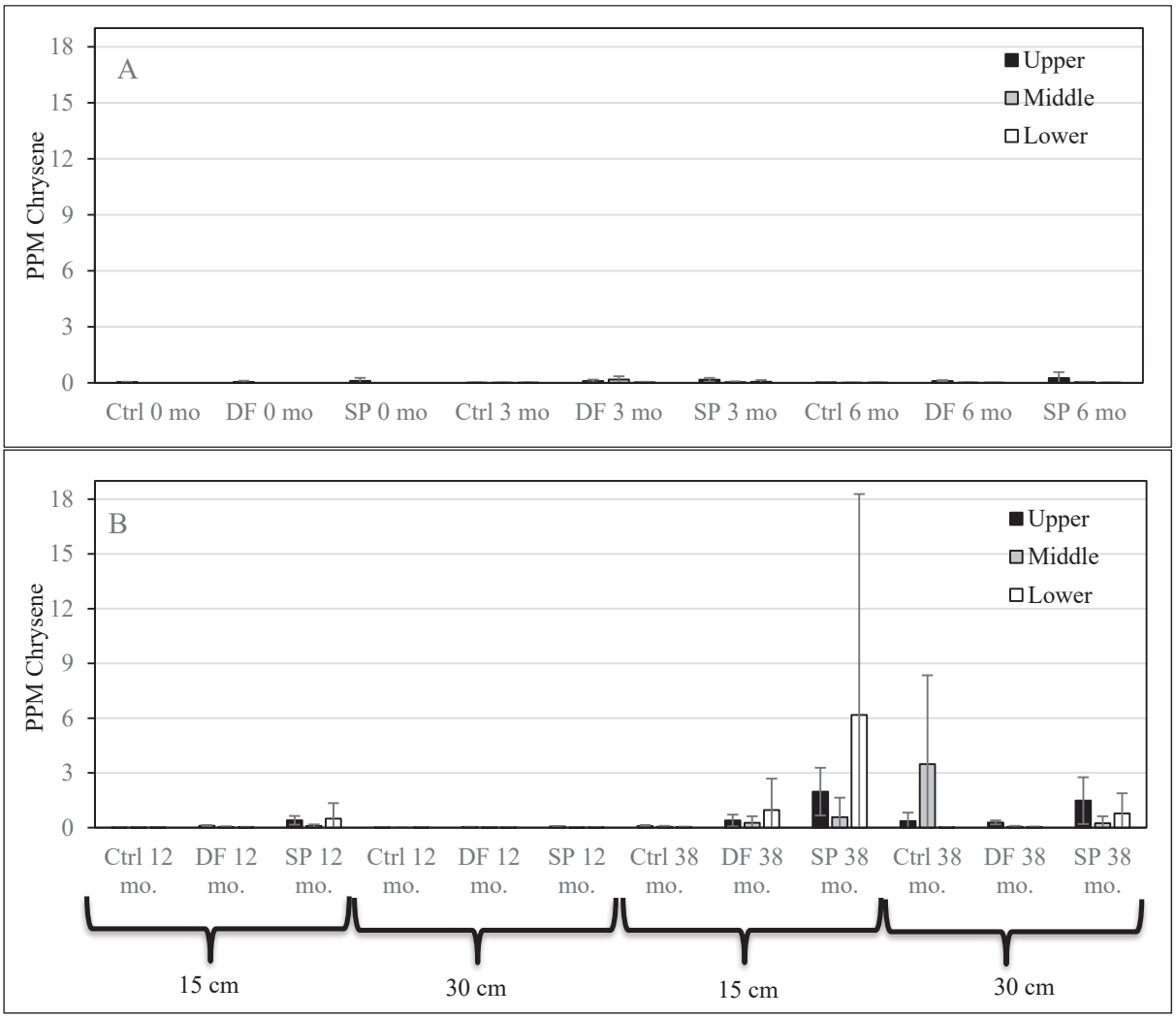


Figure 5. Average chrysene concentrations found in soils around creosote-treated Douglas-fir and southern pine posts at (A) 0–6 mo, 15 cm from the post surface; and (B) 12–38 mo after installation, 15 and 30 cm from the post surface. Soil was sampled at three depths in the soil column: 0–15 cm (upper), 15–30 cm (middle), and 30–46 cm (lower). Error bars are plus or minus one standard deviation.

period. This suggests that migration in the first 12 mo was largely limited to within a 15-cm radius.

An increase in benzo [a] pyrene concentrations in soil was detectable 38 mo after installation. Benzo [a] pyrene concentrations in Douglas-fir posts 15 cm from the post surface were similar to those found in previous sampling periods, except for an increase in the lower 30–46 cm sampled. In the same 38-mo sampling period at 30 cm from the post surface, benzo [a] pyrene concentrations also increased for Douglas-fir posts, but were around concentration levels found in the background and in the 3-mo sampling period. Similarly, an increase in benzo [a] pyrene soil concentrations was apparent after 38-mo in the 0–15 and 30–46 cm of the soil column sampled; however, concentrations were higher in southern pine posts. Benzo [a] pyrene concentrations 15 cm from the post surface in southern pine posts ranged from around 0.4 ppm to around 1.0 ppm after 38 mo, but decreased substantially 30 cm from the post, averaging around 0.1 ppm.

Soil concentrations of all 16 PAHs analyzed in this study over a 38-mo sampling period are shown in Tables S1-S5. Most of the PAHs followed one of the two trends described above for lower and higher molecular weight PAHs. These data can be used to further identify trends in PAH migration from creosote-treated commodities in ground contact. For example, these data show rapidly declining PAH concentrations with increasing distance from roundwood surfaces, even within 30 cm of the wood surface, which suggests near background levels are likely reached only a short distance farther from the posts. Previous

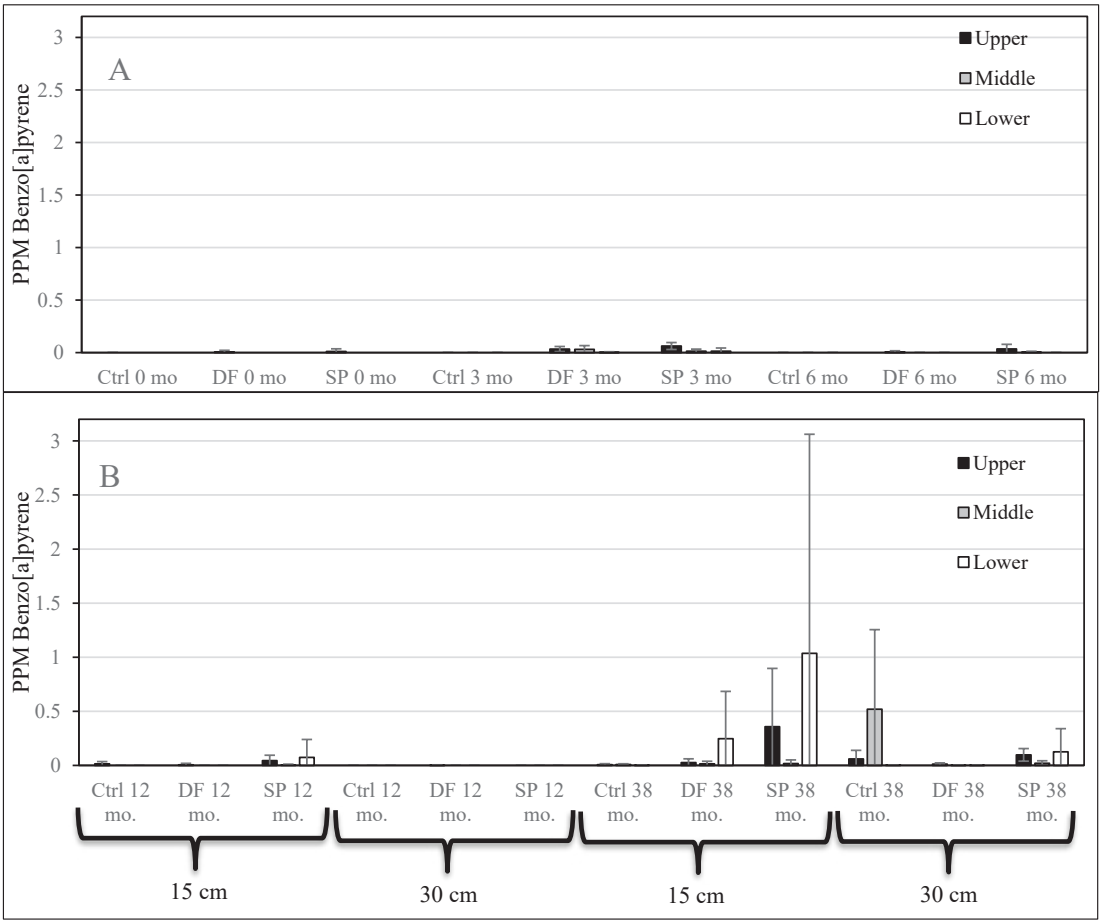


Figure 6. Average benzo [a] pyrene concentrations found in soils around creosote-treated Douglas-fir and southern pine posts at (A) 0–6 mo, 15 cm from the post surface; and (B) 12–38 mo after installation, 15 and 30 cm from the post surface. Soil was sampled at three depths in the soil column: 0–15 cm (upper), 15–30 cm (middle), and 30–46 cm (lower). Error bars are plus or minus one standard deviation.

studies have shown that PAH migration from creosote-treated utility poles was spatially limited, with migration of nearly all of the 13 PAHs assessed limited to within 20 cm of the pole surface (EPRI 1997; NAWPC 2020).

To date, the trends identified show higher initial accumulation of lighter PAHs near the post surfaces, followed by dissipation to background levels or lower. Heavier PAHs show a different pattern where they were found in greater abundance in the latest sampling point, which suggests that mobilization of these chemicals from the post surfaces is slower, reflecting their lower solubility in water. This work provides a better understanding of how creosote-treated roundwood can impact soils and provides utilities with a benchmark to assess the impact of creosote-treated utility poles in the initial years after installation. This study is still in the ground and is continuing to be sampled. Subsequent samplings will expand to a distance of 46 cm from the post surface to attempt to delineate the outer limits of detectable PAH increases around the creosote-treated posts.

Conclusions

PAH migration from Douglas-fir and southern pine posts was highly varied among PAHs over the 38-mo sampling period, and in many cases, concrete patterns were not discernible. Overall, southern pine posts tended to yield higher soil PAH concentrations around the posts due to the higher creosote loading in the species for samples utilized in this study. For some of the lighter PAHs, significant environmental inputs not attributable to creosote were detected at the study start and during the sampling period. This indicates that for those PAHs found in controls or at the initial sampling point, the proportion of PAH originating from creosote versus other environmental inputs could not be quantified.

Lighter PAHs found around creosote-treated posts in some cases showed an initial impulse in the early sampling points that dissipated in magnitude in the later sampling periods. Heavier PAHs showed a different pattern of migration and

were more frequently found around creosote-treated posts, but were detected less often overall across the samples. Some of the heavier PAHs were more often identified among replicate samples taken from soils closer to the post surface, although some were still detected at the more distant sampling point after 38 mo. This study shows a complex migration dynamics among different PAH components that is in part dependent on creosote concentration, distance from the posts, time since installation, and non-creosote environmental inputs.

Acknowledgements

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References

AWPA (2020) A6-20 Standard method for the determination of retention of oil-type preservatives from small samples. American Wood Protection Association, Birmingham, AL.

Baechler RH, Stamm AJ (1954) Wood. I Eng Chem 46(10):2127–2130. https://doi.org/10.1021/ie50538a038

Baimatova N, Koziel JA, Kenessov B (2017) Passive sampling and analysis of naphthalene in internal combustion engine exhaust with retracted SPME Device and GC-MS. Atmosphere 8(7). https://doi.org/10.3390/atmos8070130

Bestari K, Robinson R, Solomon K, Steele T, Day K, Sibley P (1998) Distribution and composition of polycyclic aromatic hydrocarbons within experimental microcosms treated with creosote-impregnated Douglas-fir pilings. Environ Toxicol Chem 17(12):2369–2377. https://doi.org/10.1002/etc.5620171202

Bolin CA, Smith ST (2013) Life Cycle Assessment of Creosote-Treated Wooden Railroad Crossties in the US with Comparisons to Concrete and Plastic Composite Railroad Crossties. 2013. https://doi.org/10.4236/jtts.2013.32015

Brooks K (2004) Polycyclic aromatic hydrocarbon migration from creosote-treated railway ties into ballast and adjacent wetlands (No. FPL−RP−617; p. 53). U.S. Department of Agriculture Forest Service, Forest Products Laboratory.

Brooks K (2020) Preserved Wood Utility Poles and the Environment (Technical Bulletin Nos. 19-E-302; p. 12). North American Wood Pole Council.

Cargouët M, Jeannee N, Vidart B, Gregori P (2018) Polycyclic aromatic hydrocarbon (PAH) levels in environmental media potentially impacted by reused or stored creosote-treated railway ties. Environ Sci Pollut Res 25(18):17409–17424. https://doi.org/10.1007/s11356-018-1910-9

Coulon F, Pelletier E, Gourhant L, Delille D (2005) Effects of nutrient and temperature on degradation of petroleum hydrocarbons in contaminated sub-Antarctic soil. Chemosphere 58(10):1439–1448. https://doi.org/10.1016/j.chemosphere.2004.10.007

Duncan DL, Carls MG, Rice SD, Stekoll MS (2017) The toxicity of creosote-treated wood to Pacific herring embryos and characterization of polycyclic aromatic hydrocarbons near creosoted pilings in Juneau, Alaska. Environ Toxicol Chem 36(5), 1261–1269. https://doi.org/10.1002/etc.3653

Eisler R (1987) Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: A synoptic review (Biological Report 85 No. 11; p. 81). U.S. Fish and Wildlife Service.

Electric Power Research Institute (EPRI). (1997). Pole preservatives in soils adjacent to in-service utility poles in the United States (Report No. TR-108598). https://www.epri.com/research/products/TR-108598.

Gallacher C, Thomas R, Taylor C, Lord R, Kalin RM (2017) Comprehensive composition of Creosote using comprehensive two-dimensional gas chromatography time-of-flight mass spectrometry (GCxGC-TOFMS). Chemosphere 178:34–41. https://doi.org/10.1016/j.chemosphere.2017.03.050

Gewurtz SB, Lazar R, Douglas Haffner G (2000) Comparison of polycyclic aromatic hydrocarbon and polychlorinated biphenyl dynamics in benthic invertebrates of Lake Erie, USA. Environ Toxicol Chem 19(12):2943–2950. https://doi.org/10.1002/etc.5620191215

Goyette D, Brooks KM (1998) Creosote Evaluation: Phase II Sooke Basin Study – Baseline to 535 Days Post Construction 1995–1996. Prepared for the Creosote Evaluation Steering Committee Regional Program, Report PR98-04.

Kang, S-M, Morrell JJ, Simonsen J, Lebow S (2005). Creosote movement from treated wood immersed in fresh water. *Forest Prod J 55*(12):42–46.

Kim EJ, Choi S-D, Chang Y-S (2011) Levels and patterns of polycyclic aromatic hydrocarbons (PAHs) in soils after forest fires in South Korea. Environ Sci Pollut Res 18(9):1508–1517. https://doi.org/10.1007/s11356-011-0515-3

Konkler MJ, Cappellazzi J, Presley G, Morrell JJ (2020) Migration of creosote components from timbers treated with creosote and processed using Best Management Practices. J Environ Manag 276. https://doi.org/10.1016/j.jenvman.2020.111270

Moret S, Purcaro G, Conte LS (2007) Polycyclic aromatic hydrocarbon (PAH) content of soil and olives collected in areas contaminated with creosote released from old railway ties. Sci Total Environ 386(1):1–8. https://doi.org/10.1016/j.scitotenv.2007.07.008

Mueller JG, Chapman PJ, Pritchard PH (1989). Creosote-contaminated sites. Their potential for bioremediation. Environ Sci Technol 23(10):1197–1201. https://doi.org/10.1021/es00068a003

Murphy BL, Brown J (2005) Environmental forensics aspects of PAHs from wood treatment with creosote compounds. Environ Forensics 6(2):151–159. https://doi.org/10.1080/15275920590952829

Navarro KM, Cisneros R, Schweizer D, Chowdhary P, Noth EM, Balmes JR, Hammond SK (2019) Incident command post exposure to polycyclic aromatic hydrocarbons and particulate matter during a wildfire. J Occup Environ Hyg 16(11):735–744. https://doi.org/10.1080/15459624.2019.1657579

Nestler FH Max (1974) Characterization of wood-preserving coal-tar creosote by gas-liquid chromatography. Anal Chem 46(1):46–53. https://doi.org/10.1021/ac60337a008

North American Wood Pole Council (NAWPC). (2020). Preserved wood utility poles and the environment (Technical Bulletin No. 19-E-302). https://woodpoles.org/wp-content/uploads/TB_Pole_Enviro.pdf

O'Malley KE, Ghetu CC, Rohlman D, Anderson KA (2024) Assessing wildfire impact on diffusive flux of parent and alkylated PAHs: A pilot study of soil-air chemical movement before, during, and after wildfires. Environ Sci Technol 58(52):23117–23126. https://doi.org/10.1021/acs.est.4c09139

RTA (2025) Questions About the Railway Tie Association. Railway Tie Association. https://www.rta.org/faq

Shupe, T. F., Hse, C. Y., & Roliadi, H. (2006). Removal of creosote from wood particles at different horizontal and vertical locations of decommissioned poles using steam treatment. *Wood and Fiber Science, 38*(2), 345–350

US EPA (1981) Priority Pollutant List. 40 CFR Part 423, Appendix A

Vlosky RP (2009, February 16). Statistical Overview of the U.S. Wood Preserving Industry: 2007. Louisiana Forest Products Development Center, Louisiana State University Agricultural Center, Baton Rouge. https://www.researchgate.net/publication/343921608_STATISTICAL_OVERVIEW_OF_THE_US_WOOD_PRESERVING_INDUSTRY_2007

Webster, P.D. 1992. The Wood Crosstie, A 150 Year Success Story: The Railway Tie Association & the National Association of Railroad Tie Producers, A Three-Quarters of a Century History. Railway Tie Association, Gulf Shores, AL. 272 p.

Wilson S, Jones K (1993) Bioremediation of soil contaminated with polynuclear aromatic-hydrocarbons (PAHS)—A Review. Environ Pollut 81(3):229–249. https://doi.org/10.1016/0269-7491(93)90206-4

Appendix: Supplemental data

Table S1. Average concentrations of 16 polycyclic aromatic hydrocarbons measured in this study in soils isolated from post holes dug for the installation of creosote-treated Douglas-fir and southern pine posts, as well as untreated Douglas-fir control posts at the beginning of this study.

Naphthalene concentration (ppb)[a]		
Post type to be installed (species)	Creosote treatment [b]	Post hole (background)
Douglas-fir	−	1013.4 (238.1)
Douglas-fir	+	1191.9 (767.5)
Southern pine	+	624.9 (397.6)
Acenaphthylene concentration (ppb)[a]		
Species	Creosote	Post hole (background)
Douglas-fir	−	0.0 (0.0)
Douglas-fir	+	0.1 (0.1)
Southern pine	+	0.0 (0.0)
Acenaphthene concentration (ppb)[a]		
Species	Creosote	Post hole (background)
Douglas-fir	−	196.7 (60.0)
Douglas-fir	+	252.5 (98.9)
Southern pine	+	114.9 (39.5)
Fluorene concentration (ppb)[a]		
Species	Creosote	Post hole (background)
Douglas-fir	−	49.2 (14.9)
Douglas-fir	+	69.6 (24.3)
Southern pine	+	48.6 (36.9)
Phenanthrene concentration (ppb)[a]		
Species	Creosote	Post hole (background)
Douglas-fir	−	58.6 (6.7)
Douglas-fir	+	53.1 (51.6)
Southern pine	+	75.7 (85.0)
Anthracene concentration (ppb)[a]		
Species	Creosote	Post hole (background)
Douglas-fir	−	23.9 (3.8)
Douglas-fir	+	18.4 (19.2)
Southern pine	+	41.9 (66.3)
Fluoranthene concentration (ppb)[a]		
Species	Creosote	Post hole (background)
Douglas-fir	−	54.9 (3.3)
Douglas-fir	+	57.4 (37.0)
Southern pine	+	92.0 (93.5)

Pyrene concentration (ppb)[a]		
Species	Creosote	Post hole (background)
Douglas-fir	−	36.0 (3.9)
Douglas-fir	+	37.2 (21.6)
Southern pine	+	57.8 (59.9)
Benz[a]anthracene concentration (ppb)[a]		
Species	Creosote	Post hole (background)
Douglas-fir	−	26.3 (1.4)
Douglas-fir	+	20.3 (11.7)
Southern pine	+	32.8 (32.4)
Chrysene concentration (ppb)[a]		
Species	Creosote	Post hole (background)
Douglas-fir	−	44.4 (12.6)
Douglas-fir	+	47.5 (64.3)
Southern pine	+	103.3 (164.0)
Benzo[b + k] fluoranthene concentration (ppb)[a]		
Species	Creosote	Post hole (background)
Douglas-fir	−	44.4 (12.6)
Douglas-fir	+	47.5 (64.3)
Southern pine	+	103.3 (164.0)
Benzo[a]pyrene concentration (ppb)[a]		
Species	Creosote	Post hole (background)
Douglas-fir	−	0.0 (0.0)
Douglas-fir	+	6.7 (15.0)
Southern pine	+	11.1 (24.9)
Indeno[1,2,3-cd]pyrene concentration (ppb)[a]		
Species	Creosote	Post hole (background)
Douglas-fir	−	0.0 (0.0)
Douglas-fir	+	8.7 (19.4)
Southern pine	+	0.0 (0.0)
Benzo[g,h,i]perylene concentration (ppb)[a]		
Species	Creosote	Post hole (background)
Douglas-fir	−	0.0 (0.0)
Douglas-fir	+	8.3 (18.6)
Southern pine	+	0.0 (0.0)
Dibenz[a,h]anthracene concentration (ppb)[a]		
Species	Creosote	Post hole (background)
Douglas-fir	–	29.3 (41.4)
Douglas-fir	+	9.4 (20.9)
Southern pine	+	0.0 (0.0)

[a]Values are means of three replicate samples with one standard deviation in parentheses.
[b]Untreated posts indicated with − ; creosote treated posts indicated with + .

Table S2. Average concentrations of 16 polycyclic aromatic hydrocarbons measured in this study found in soils around creosote-treated Douglas-fir and southern pine posts 3 mo after post installation. Soil was collected 15 cm from the post surface and at three depths in the soil column: 0–15 cm (upper), 15–30 cm (middle), and 30–46 cm (lower). Standard deviations for five replicate soil samples around treated posts and two replicate extracts around untreated posts are also shown.

Naphthalene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	260.7 (193.4)	280.0 (251.7)	199.5 (46.6)
Douglas-fir	+	395.6 (74.8)	489.8 (174.2)	352.9 (202.1)
Southern pine	+	451.0 (127.8)	549.9 (515.2)	290.4 (163.2)
Acenaphthylene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Douglas-fir	+	0.0 (0.1)	0.1 (0.1)	0.0 (0.0)
Southern pine	+	0.1 (0.1)	0.1 (0.1)	0.2 (0.1)
Acenaphthene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	29.3 (3.4)	31.8 (25.3)	52.5 (37.5)
Douglas-fir	+	104.2 (66.7)	119.2 (67.7)	108.0 (57.2)
Southern pine	+	159.5 (69.5)	117.9 (42.6)	184.3 (115.9)
Fluorene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 mm	15–30 cm	30–45 cm
Douglas-fir	−	13.0 (4.3)	9.5 (5.9)	16.0 (13.7)
Douglas-fir	+	45.7 (21.0)	53.3 (27.9)	34.2 (17.6)
Southern pine	+	84.3 (33.2)	40.4 (8.9)	79.0 (71.8)
Phenanthrene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	11.8 (6.5)	5.8 (2.4)	11.7 (9.7)
Douglas-fir	+	117.7 (53.2)	128.6 (90.6)	41.0 (33.1)
Southern pine	+	168.0 (80.5)	59.3 (60.0)	84.7 (87.7)
Anthracene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	3.4 (4.8)	3.8 (1.6)	3.8 (3.6)
Douglas-fir	+	404.8 (512.3)	299.1 (595)	273.2 (648.1)
Southern pine	+	30.3 (17.3)	13.5 (14.1)	16.5 (15.8)
Fluoranthene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	33.9 (15.1)	27.5 (7.8)	32.0 (7.1)
Douglas-fir	+	327.0 (141.2)	347.5 (268.4)	108.5 (66.7)
Southern pine	+	430.7 (200.1)	165.4 (180.0)	136.0 (158.6)

[a]Values are means of three replicate samples with one standard deviation in parentheses.

Table S2 (*continued*). Average concentrations of 16 polycyclic aromatic hydrocarbons measured in this study found in soils around creosote-treated Douglas-fir and southern pine posts 3 mo after post installation.

Pyrene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	14.3 (11.0)	12.1 (2.7)	21.4 (3.8)
Douglas-fir	+	195.7 (83.0)	207.8 (158.8)	69.0 (39.8)
Southern pine	+	265.2 (122.9)	104.9 (107.7)	85.5 (95.9)
Benz[a]anthracene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	12.9 (6.1)	10.9 (3.5)	12.0 (1.3)
Douglas-fir	+	51.8 (19.5)	71.9 (60.1)	20.0 (12.4)
Southern pine	+	85.1 (51.6)	26.4 (18.1)	29.1 (29.3)
Chrysene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	10.1 (12.1)	6.3 (3.8)	10.2 (7.3)
Douglas-fir	+	95.3 (78.4)	174.5 (174.6)	29.3 (26.7)
Southern pine	+	166.6 (100.1)	38.6 (38.1)	56.8 (92.0)
Benzo[j] and [k] fluoranthene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	10.1 (12.1)	6.3 (3.8)	10.2 (7.3)
Douglas-fir	+	95.3 (78.4)	174.5 (174.6)	29.3 (26.7)
Southern pine	+	166.6 (100.1)	38.6 (38.1)	56.8 (92.0)
Benzo[a]pyrene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Douglas-fir	+	34.0 (24.3)	30.2 (36.3)	2.5 (5.6)
Southern pine	+	62.7 (33.1)	13.6 (19.7)	13.5 (30.3)
Indeno[1,2,3-cd]pyrene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Douglas-fir	+	0.0 (0.0)	14.4 (19.8)	0.0 (0.0)
Southern pine	+	9.1 (20.4)	0.0 (0.0)	0.0 (0.0)
Benzo[g,h,i]perylene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Douglas-fir	+	0.0 (0.0)	9.7 (13.3)	0.0 (0.0)
Southern pine	+	7.9 (17.6)	0.0 (0.0)	0.0 (0.0)
Dibenz[a,h]anthracene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Douglas-fir	+	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Southern pine	+	7.3 (16.4)	0.0 (0.0)	0.0 (0.0)

[a]Values are means of three replicate samples with one standard deviation in parentheses.

Table S3. Concentrations of 16 polycyclic aromatic hydrocarbons measured in this study found in soils around creosote-treated Douglas-fir and southern pine posts 6 mo after post installation. Soil was collected 15 cm from the post surface and at three depths in the soil column: 0–15 cm (upper), 15–30 cm (middle), and 30–46 cm (lower). Standard deviations for five replicate soil samples around treated posts and two replicate extracts around untreated posts are also shown.

Naphthalene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	183.1 (89.3)	157.8 (120.3)	139.0 (119.0)
Douglas-fir	+	243.8 (146.5)	288.6 (135.7)	138.3 (74.7)
Southern pine	+	229.2 (87.7)	243.3 (80.8)	138.3 (74.7)
Acenaphthylene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Douglas-fir	+	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Southern pine	+	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)
Acenaphthene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	84.1 (63.6)	65.4 (49.9)	64.4 (38.3)
Douglas-fir	+	63.7 (31.2)	94.2 (49.9)	74.2 (37.5)
Southern pine	+	58.9 (29.2)	68.2 (42.7)	74.2 (37.5)
Fluorene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	30.8 (8.7)	14.6 (12.1)	20.6 (13.6)
Douglas-fir	+	25.9 (19.4)	20.8 (10.7)	17.4 (12.3)
Southern pine	+	65.0 (91.1)	18.7 (8.8)	17.4 (12.3)
Phenanthrene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	35.2 (25.2)	12.6 (6.7)	25.7 (21.6)
Douglas-fir	+	65.1 (10.0)	18.5 (7.2)	12.2 (4.0)
Southern pine	+	153.7 (147.6)	26.9 (12.9)	12.2 (4.0)
Anthracene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	6.6 (9.4)	0.0 (0.0)	3.3 (4.7)
Douglas-fir	+	36.1 (26.2)	0.9 (2.1)	3.1 (4.7)
Southern pine	+	140.1 (260.4)	8.7 (7.9)	3.1 (4.7)
Fluoranthene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	44.8 (22.0)	25.9 (6.2)	54.2 (42.0)
Douglas-fir	+	251.4 (140.1)	67.3 (55.0)	26.5 (6.3)
Southern pine	+	437.3 (428.4)	108.9 (109.5)	26.5 (6.3)

[a]Values are means of three replicate samples with one standard deviation in parentheses.

Table S3 (*continued*). Concentrations of 16 polycyclic aromatic hydrocarbons measured in this study found in soils around creosote-treated Douglas-fir and southern pine posts 6 mo after post installation. Soil was collected 15 cm from the post surface and at three depths in the soil column: 0–15 cm (upper), 15–30 cm (middle), and 30–46 cm (lower).

Pyrene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	27.6 (10.6)	14.7 (0.1)	39.5 (45.7)
Douglas-fir	+	162.9 (84.3)	41.7 (29.7)	12.9 (10.6)
Southern pine	+	311.8 (302.3)	74.1 (73.8)	12.9 (10.6)
Benz[a]anthracene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	25.6 (8.2)	25.4 (4.4)	27.9 (5.8)
Douglas-fir	+	105.4 (27.1)	198.8 (182.5)	30.0 (20.7)
Southern pine	+	148.0 (124.0)	54.1 (45.3)	30.0 (20.7)
Chrysene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	22.9 (9.5)	4.9 (6.9)	9.6 (13.5)
Douglas-fir	+	95.1 (49.4)	11.8 (17.8)	2.5 (3.5)
Southern pine	+	253.2 (320.8)	31.9 (24.9)	2.5 (3.5)
Benzo[j] and [k] fluoranthene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	22.9 (9.5)	4.9 (6.9)	9.6 (13.5)
Douglas-fir	+	95.1 (49.4)	11.8 (17.8)	2.5 (3.5)
Southern pine	+	253.2 (320.8)	31.9 (24.9)	2.5 (3.5)
Benzo[a]pyrene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 mm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Douglas-fir	+	7.3 (10.1)	0.0 (0.0)	0.0 (0.0)
Southern pine	+	34.7 (44.2)	3.9 (8.8)	0.0 (0.0)
Indeno[1,2,3-cd]pyrene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Douglas-fir	+	5.5 (12.3)	0.0 (0.0)	0.0 (0.0)
Southern pine	+	35.9 (57.6)	4.0 (9.0)	0.0 (0.0)
Benzo[g,h,i]perylene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Douglas-fir	+	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Southern pine	+	10.8 (24.1)	0.0 (0.0)	0.0 (0.0)
Dibenz[a,h]anthracene concentration (ppb)[a]				
Species	Creosote	Soil sampling depth		
		0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Douglas-fir	+	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Southern pine	+	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

[a]Values are means of three replicate samples with one standard deviation in parentheses.

Table S4. Concentrations of 16 polycyclic aromatic hydrocarbons measured in this study found in soils around creosote-treated Douglas-fir and southern pine posts 12 mo after post installation. Soil was collected 15 cm from the post surface and at three depths in the soil column: 0–15 cm (upper), 15–30 cm (middle), and 30–46 cm (lower). Standard deviations for five replicate soil samples around treated posts and two replicate extracts around untreated posts are also shown.

Naphthalene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	70.2 (4.1)	68.9 (7.0)	51.4 (9.0)	45.9 (8.7)	50.8 (26.2)	45.5 (11.4)
Douglas-fir	+	80.1 (48.4)	74.7 (9.9)	45.9 (11.2)	76.8 (64.1)	64.6 (17.1)	50.7 (20.6)
Southern pine	+	114.6 (56.5)	108.5 (93.0)	59.8 (37.3)	104.3 (47.2)	55.6 (38.6)	44.3 (33.0)
Acenaphtylene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Douglas-fir	+	10.7 (17.6)	19.5 (21.4)	13.4 (12.5)	10.3 (14.5)	14.3 (21.2)	10.9 (9.1)
Southern pine	+	30.1 (14.2)	37.0 (21.9)	26.5 (17.9)	33.6 (20.6)	16.9 (12.8)	10.6 (13.5)
Acenaphthene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	44.1 (16.4)	48.7 (18.6)	30.7 (17.4)	25.2 (10.9)	18.9 (8.4)	30.8 (12.7)
Douglas-fir	+	59.2 (28.7)	86.5 (58.4)	80.2 (51.3)	57.1 (37.8)	67.6 (78.0)	58.7 (34.4)
Southern pine	+	138.9 (104.4)	303.8 (289.4)	286.4 (250.1)	137.4 (70.2)	57.6 (40.0)	38.5 (33.1)
Fluorene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	48.7 (1.3)	45.4 (11.1)	28.6 (12.9)	20.5 (12.4)	15.3 (5.2)	20.0 (10.9)
Douglas-fir	+	44.4 (12.0)	61.9 (39.0)	76.4 (63.6)	37.3 (15.0)	60.8 (83.8)	47.0 (44.2)
Southern pine	+	67.4 (21.1)	209.6 (133.5)	355.0 (372.4)	83.8 (44.1)	42.6 (27.6)	32.7 (20.7)
Phenanthrene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	50.1 (9.3)	32.3 (9.0)	30.6 (5.8)	35.6 (16.4)	30.6 (9.0)	18.8 (26.7)
Douglas-fir	+	70.4 (18.6)	112.5 (119.3)	349.2 (472.1)	47.1 (11.8)	110.6 (185.8)	61.1 (70.0)
Southern pine	+	178.0 (70.0)	323.3 (231.9)	1402.2 (2139.8)	92.0 (31.5)	33.0 (9.8)	33.4 (16.1)
Anthracene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	3.3 (4.6)	0.0 (0.0)	4.0 (5.6)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Douglas-fir	+	8.2 (6.8)	6.5 (6.9)	14.8 (12.8)	1.7 (1.5)	1.6 (3.5)	1.3 (1.9)
Southern pine	+	20.3 (5.8)	21.1 (16.5)	114.0 (145.6)	5.3 (7.2)	2.1 (4.6)	0.6 (1.3)
Flouranthene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	63.3 (9.8)	23.3 (32.9)	37.3 (7.7)	35.6 (15.8)	33.1 (15.1)	17.3 (24.4)
Douglas-fir	+	168.3 (37.8)	104.9 (44.3)	158.3 (147.9)	71.3 (16.5)	39.3 (13.0)	33.5 (22.7)
Southern pine	+	441.7 (200.0)	178.3 (110.0)	1714.1 (3341.8)	130.1 (57.6)	36.6 (12.1)	44.9 (27.6)

[a]Values are means of three replicate samples with one standard deviation in parentheses.

Table S4 (*continued*). Concentrations of 16 polycyclic aromatic hydrocarbons measured in this study found in soils around creosote-treated Douglas-fir and southern pine posts 12 mo after post installation. Soil was collected 15 cm from the post surface and at three depths in the soil column: 0–15 cm (upper), 15–30 cm (middle), and 30–46 cm (lower).

Pyrene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	54.0 (4.2)	21.6 (30.5)	29.9 (11.7)	25.5 (16.4)	29.9 (15.7)	10.2 (14.4)
Douglas-fir	+	115.3 (22.0)	74.8 (27.3)	102.0 (90.5)	52.6 (12.1)	31.6 (8.1)	18.2 (18.9)
Southern pine	+	312.1 (143.2)	121.5 (72.6)	1173.3 (2285.9)	96.4 (42.2)	28.1 (10.8)	30.5 (22.3)
Benz[a]anthracene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	11.1 (15.7)	8.8 (12.5)	2.1 (3.0)	6.2 (8.7)	0.0 (0.0)	1.9 (2.7)
Douglas-fir	+	31.2 (10.7)	13.9 (13.5)	6.3 (9.5)	14.2 (2.2)	0.6 (1.4)	1.4 (3.2)
Southern pine	+	106.3 (69.8)	26.3 (18.4)	550.8 (1162.6)	24.2 (18.8)	2.0 (3.0)	3.7 (6.4)
Chrysene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	9.0 (2.7)	3.2 (4.5)	0.9 (1.3)	6.8 (9.5)	0.0 (0.0)	3.6 (5.0)
Douglas-fir	+	100.7 (42.5)	33.8 (43.1)	24.1 (22.6)	35.0 (10.8)	1.4 (1.9)	9.0 (20.2)
Southern pine	+	401.7 (238.7)	95.3 (80.1)	490.4 (854.6)	59.1 (31.8)	4.7 (3.6)	10.6 (21.9)
Benzo[j] and [k] fluoranthene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	9.0 (2.7)	3.2 (4.5)	0.9 (1.3)	6.8 (9.5)	0.0 (0.0)	3.6 (5.0)
Douglas-fir	+	100.7 (42.5)	33.8 (43.1)	24.1 (22.6)	35.0 (10.8)	1.4 (1.9)	9.0 (20.2)
Southern pine	+	401.7 (238.7)	95.3 (80.1)	490.4 (854.6)	59.1 (31.8)	4.7 (3.6)	10.6 (21.9)
Benzo[a]pyrene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	14.7 (20.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Douglas-fir	+	5.9 (13.2)	0.0 (0.0)	0.0 (0.0)	1.7 (3.7)	0.0 (0.0)	0.0 (0.0)
Southern pine	+	43.7 (50.6)	3.5 (7.9)	74.1 (165.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Indeno[1,2,3-cd]pyrene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Douglas-fir	+	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Southern pine	+	14.2 (31.7)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Benzo[g,h,i]perylene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Douglas-fir	+	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Southern pine	+	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Dibenz[a,h]anthracene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Douglas-fir	+	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Southern pine	+	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

[a]Values are means of three replicate samples with one standard deviation in parentheses.

Table S5. Concentrations of 16 polycyclic aromatic hydrocarbons measured in this study found in soils around creosote-treated Douglas-fir and southern pine posts 38 mo after post installation. Soil was collected 15 cm from the post surface and at three depths in the soil column: 0–15 cm (upper), 15–30 cm (middle), and 30–46 cm (lower). Standard deviations for five replicate soil samples around treated posts and two replicate extracts around untreated posts are also shown.

Naphthalene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	27.7 (39.1)	56.2 (61.5)	32.9 (10.8)	77.7 (7.6)	946.1 (1338.0)	60.4 (29.7)
Douglas-fir	+	60.8 (57.3)	124.9 (103.6)	95.7 (47.4)	112.5 (85.8)	89.8 (74.8)	0.0 (0.0)
Southern pine	+	105.3 (57.9)	48.1 (33.4)	107.3 (140.4)	116.6 (69.4)	78.0 (32.3)	94.1 (64.1)
Acenaphthylene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.1 (0.2)	0.1 (0.1)	0.0 (0.0)	1.0 (1.4)	32.5 (45.9)	1.4 (1.4)
Douglas-fir	+	59.3 (92.5)	0.0 (0.0)	0.2 (0.4)	2.4 (2.8)	1.9 (4.0)	0.0 (0.0)
Southern pine	+	47.3 (78.4)	5.2 (8.2)	12.4 (16.9)	25.9 (38.9)	40.9 (87.0)	4.8 (6.9)
Acenaphthene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	57.7 (81.6)	110.1 (133.3)	25.8 (0.2)	84.9 (18.3)	2297.2 (3248.7)	86.5 (65.7)
Douglas-fir	+	26.3 (21.2)	42.8 (45.4)	502.6 (878.8)	56.2 (59.8)	25.5 (27.3)	0.0 (0.0)
Southern pine	+	75.4 (39.7)	55.1 (59.2)	244.3 (273.4)	67.9 (56.8)	204.3 (293.5)	199.8 (290.4)
Fluorene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	45.1 (63.7)	50.0 (55.7)	9.9 (3.3)	56.2 (32.3)	848.0 (1199.2)	42.6 (41.6)
Douglas-fir	+	8.0 (6.7)	9.7 (14.0)	451.5 (1014.7)	13.3 (9.1)	8.5 (10.8)	0.0 (0.0)
Southern pine	+	53.5 (36.5)	31.9 (41.7)	228.9 (268.4)	37.5 (27.4)	136.7 (202.8)	144.6 (240.7)
Phenanthrene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	294.8 (416.9)	79.7 (78.8)	33.1 (13.0)	158.4 (164.0)	1859.6 (2629.9)	45.8 (37.0)
Douglas-fir	+	389.6 (454.8)	310.8 (523.7)	297.3 (537.8)	236.8 (152.0)	30.9 (32.7)	0.0 (0.0)
Southern pine	+	522.7 (299.4)	220.4 (250.7)	747.3 (709.0)	458.0 (333.2)	301.6 (259.7)	692.3 (1022.4)
Anthracene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	303.3 (428.9)	39.4 (48.7)	26.0 (15.8)	14.2 (6.8)	258.5 (365.6)	15.6 (21.0)
Douglas-fir	+	404.8 (512.3)	299.1 (595.0)	273.2 (648.1)	157.5 (237.7)	1.9 (3.2)	0.0 (0.0)
Southern pine	+	526.5 (407.1)	204.5 (291.4)	666.3 (593.4)	289.4 (315.7)	210.0 (281.9)	421.8 (910.0)
Fluoranthene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	74.5 (105.4)	79.0 (95.5)	16.0 (3.3)	258.2 (334.2)	3202.6 (4529.2)	31.8 (18.1)
Douglas-fir	+	1206.6 (1404.1)	820.2 (1410.0)	3086.3 (7075.0)	627.5 (438.0)	59.1 (68.5)	0.0 (0.0)
Southern pine	+	1734.3 (1714.7)	545.6 (775.6)	5300.8 (9786.2)	1194.2 (975.2)	250.4 (303.3)	791.2 (943.8)

[a]Values are means of three replicate samples with one standard deviation in parentheses.

Table S5 (*continued*). Concentrations of 16 polycyclic aromatic hydrocarbons measured in this study found in soils around creosote-treated Douglas-fir and southern pine posts 38 mo after post installation. Soil was collected 15 cm from the post surface and at three depths in the soil column: 0–15 cm (upper), 15–30 cm (middle), and 30–46 cm (lower).

Pyrene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	28.7 (40.6)	53.0 (63.2)	8.3 (5.2)	167.6 (212.6)	1937.6 (2740.2)	22.0 (12.2)
Douglas-fir	+	741.3 (858.8)	506.3 (854.7)	2083.2 (4770.5)	379.8 (263.5)	35.3 (40.6)	0.0 (0.0)
Southern pine	+	1190.3 (1096.5)	356.2 (506.5)	3631.3 (6747.4)	818.1 (657.0)	159.7 (200.2)	495.9 (604.2)
Benz[a]anthracene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.4 (0.5)	10.8 (12.2)	1.5 (2.1)	351.9 (493.7)	351.9 (497.6)	2.7 (2.1)
Douglas-fir	+	322.6 (320.3)	216.6 (346.0)	972.9 (1776.7)	114.8 (136.5)	1.3 (2.2)	0.0 (0.0)
Southern pine	+	1498.7 (1560.0)	434.6 (1025.4)	6296.4 (12442.8)	756.2 (930.0)	122.2 (260.1)	659.8 (1200.7)
Chrysene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	83.7 (57.7)	43.4 (55.6)	29.7 (28.4)	352.0 (472.3)	3478.6 (4871.1)	15.2 (5.1)
Douglas-fir	+	393.6 (320.8)	263.5 (361.3)	961.7 (1724.8)	285.1 (110.7)	44.7 (53.6)	0.0 (0.0)
Southern pine	+	1973.5 (1308.3)	571.8 (1071.4)	6178.1 (12101.8)	1480.4 (1281.6)	244.1 (380.7)	780.1 (1103.1)
Benzo[j] and [k] fluoranthene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	33.7 (23.6)	36.8 (40.7)	11.6 (6.0)	176.8 (233.6)	1899.4 (2666.7)	22.9 (21.9)
Douglas-fir	+	358.7 (345.5)	247.9 (365.4)	918.0 (1741.6)	221.6 (119.4)	26.9 (30.0)	0.0 (0.0)
Southern pine	+	1650.3 (2083.7)	281.5 (471.3)	5474.0 (10689.7)	786.1 (670.5)	155.2 (242.8)	449.0 (630.6)
Benzo[a]pyrene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	6.6 (9.3)	8.3 (7.1)	1.5 (2.1)	60.1 (79.4)	519.9 (735.3)	3.2 (0.4)
Douglas-fir	+	26.7 (34.2)	15.2 (23.3)	247.0 (437.4)	12.4 (10.7)	1.4 (2.0)	0.0 (0.0)
Southern pine	+	358.0 (538.8)	17.7 (33.2)	1036.4 (2024.9)	97.6 (58.2)	19.5 (23.4)	125.9 (214.1)
Indeno[1,2,3-cd]pyrene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.6 (0.8)	0.0 (0.0)	22.5 (31.9)	178.0 (251.7)	0.0 (0.0)
Douglas-fir	+	8.6 (11.8)	8.7 (17.2)	88.4 (151.4)	4.8 (6.5)	0.0 (0.0)	0.0 (0.0)
Southern pine	+	181.1 (240.5)	16.3 (39.8)	473.4 (934.6)	84.9 (72.9)	8.3 (14.4)	44.8 (78.7)
Benzo[g,h,i]perylene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	25.4 (35.9)	238.5 (337.3)	0.0 (0.0)
Douglas-fir	+	6.6 (9.1)	5.6 (11.2)	77.1 (131.8)	4.4 (5.5)	0.0 (0.0)	0.0 (0.0)
Southern pine	+	162.8 (227.5)	11.9 (29.2)	401.4 (792.7)	66.8 (57.1)	9.4 (11.3)	41.9 (75.5)
Dibenz[a,h]anthracene concentration (ppb)[a]							
Species	Creosote	Soil sampling depth (15 cm away)			Soil sampling depth (30 cm away)		
		0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Douglas-fir	−	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.5)	0.8 (1.1)	0.0 (0.0)
Douglas-fir	+	0.0 (0.0)	0.0 (0.0)	9.2 (15.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Southern pine	+	26.9 (47.1)	0.0 (0.0)	94.6 (188.0)	3.4 (6.4)	0.0 (0.0)	3.0 (6.8)

[a]Values are means of three replicate samples with one standard deviation in parentheses.