The Environmental Risks Associated With The Use Of Pressure Treated Wood In Railway Rights-of-Way.

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Background. Creosote treated wood has been used extensively in railway transportation systems since 1865. Major uses include crossties, switch ties and timbers used in the construction of bridges and other structures. Transportation systems include numerous sources of PAH such as diesel engine exhaust, lubricating oils and greases, herbicides, and cargo (coal dust) to name just a few. Wan (1991) reported elevated levels of polycyclic aromatic hydrocarbons (PAH) and pentachlorophenol in ditches with standing water paralleling railway rights-of-way in British Columbia. Wan (1991) did not investigate the sources of the observed PAH. No documentation specifically describing the contribution of PAH to local environments from the use of creosote treated wood in railway transport systems was found in an extensive literature search.

Creosote is a distillate of coal tar produced as a byproduct in the manufacture of steel. It is a restricted use pesticide registered by the U.S. Environmental Protection Agency under the Federal Insecticide, Fungicide and Rodenticide Act. Brooks (1997a) has reviewed the chemistry, toxicology, transport, biodegradation, and fate of creosote treated derived PAH in aquatic environments. In addition, Brooks (1997a) has developed a computer model that predicts loss rates of PAH from immersed pressure treated wood and its transport, accumulation and degradation in sediments. Typical loss rates are 30 to 40 micrograms of PAH per square centimeter per day for new wood. Initial loss rates decline exponentially to 3 to 5 $\mu g/cm^2$-day at 25 years of age.

Creosote derived PAH accumulate in sediments or soils where they are degraded by chemical and photo-oxidation. In addition, numerous microbes metabolize PAH. The lower molecular weight compounds are degraded more quickly by microbes in the presence of oxygen and the higher weight compounds degrade more slowly, particularly in anaerobic environments (Brooks, 1997a). Polycyclic aromatic hydrocarbons are very hydrophobic and tightly bind to organic matter. They were not observed dissolved in water adjacent to creosote treated structures by Wade *et al.*, 1987. Goyette and Brooks (1999) measured dissolved PAH concentrations at a maximum of 31 parts per trillion (ng/L) immediately adjacent to a six piling dolphin that the author's believed represented a "worst case project." The point is that there is no evidence in the literature suggesting that dissolved PAH, associated with immersed creosote treated wood, reach levels associated with stress in aquatic organisms.

Creosote risk assessments. Numerous studies have been completed to evaluate the environmental risks associated with the use of creosote treated wood products in wetland and aquatic environments during the last four years. These studies have either recently been published or are in preparation for publication. Literature citations are provided in the parent documents and are not repeated in this brief summary.

Sooke Basin Creosote Evaluation Study (Environment Canada). Goyette and Brooks (1999) observed PAH concentrations as high as 18.9 μg total PAH/gram dry sediment weight within half a meter of a six piling dolphin constructed in a marine environment with very slow currents (1.89 cm/sec). Sediment PAH declined exponentially with distance and reached background levels within ten meters of the structure. No adverse effects were observed in the resident infaunal community, which was surveyed before construction and extensively monitored for 18 months following construction. Sediment toxicity was observed in laboratory bioassays within 0.65 meters of the dolphins. However, adverse effects associated with *in-situ* bioassays were limited to a small reduction in the growth of mussels (*Mytilus edulis edulis*) cultured for two years within 15 cm of the piling. Survival and reproductive success was excellent in all mussel cohorts evaluated during the Sooke Basin study. Significant differences in survival and reproductive success were not observed as a function of distance from the creosote treated structures.

The creosote model of Brooks (1997a) was evaluated three times, in both fresh water and marine environments, during the Canadian Creosote Evaluation Studies. In each case the model was found to predict approximately 30% more PAH than was actually observed. The model appears conservative from the environment's point of view.

Timber Bridge Evaluation (U.S. Forest Service) Brooks (1999b) examined six highway bridges constructed of creosote, pentachlorophenol or CCA-C for the U.S. Forest Service. The two creosote treated bridges were located in Cass County, Indiana. The CREORISK model of Brooks (1997a) predicted a loss of 37 μg TPAH/cm^2-day in the Pipe Creek environment. Each of the piling was predicted to lose 0.213 grams of PAH per day during the first year – equivalent to a drop of crankcase oil.

The suite of PAH observed in the vicinity of B146 and B148 were rich in acenaphthylene, fluorene, phenanthrene and fluoranthene. These intermediate weight compounds are consistent with new creosote contamination and the bridge structures appeared to be the source. As sedimented creosote ages, the low and intermediate weight compounds are metabolized by microbes, leaving a deposit rich in the high molecular weight compounds. This shift in PAH species was not observed at these two bridges – despite the 15 year difference in their ages. High summer temperatures likely exacerbate the loss of creosote oil from the structures – including the elevated portions. These compounds accumulate in sediments during low summer flows and likely reach a peak during the late summer and fall (when these surveys were completed). Before these accumulations can weather (as indicated by a preferential loss of the low and intermediate weight compounds), the deposits are diluted and redistributed downstream during high winter and spring flows. It is likely that this hypothetical cycle occurs in most years.

Sediment concentrations of PAH downstream from the older bridge (B148) were low and only acenaphthene and phenanthrene barely exceeded the Threshold Effects Level defined by Swartz (1999). Adverse effects were not expected in the invertebrate community but significant reductions in most biological endpoints were observed between the downstream perimeter of the bridge and 20' downstream. In contrast, no sediment toxicity was observed in laboratory bioassays when survival in downstream sediments was compared with either laboratory or upstream control sediments. These results and the analysis suggests that the invertebrate community was more effected by the presence of varying degrees of coarse particulate organic matter (CPOMP in the form of recently dropped maple leaves than on the physicochemical characteristics of the sediments.

Elevated levels of PAH were observed in sediments under and immediately downstream from two year old B146. Samples, collected from under the bridge, contained levels of naphthalene and acenaphthylene that exceeded the probable effects level given by Swartz (1999). Sediment TPAH peaked 6.0' downstream from the downstream perimeter of this bridge. The sum of all priority pollutant PAH exceeded the threshold Effects Level (TEL) of Swartz (1999) but did not exceed the Probable Effects Level (PEL) or the intermediate value ((TEL + PEL)/2) invoked as a benchmark in the evaluation. Sediment concentrations of acenaphthene and phenanthrene peaked at the 6.0' downstream station. The weight of evidence suggested that minor adverse effects might be observed under these conditions.

Pipe Creek flows through an agricultural landscape, devoted primarily to the production of corn. The stream carries a significant bedload of sand, silt and clay. Annelids and chironomids dominate the resulting invertebrate community. This community did not include significant numbers of larvae in the more sensitive Orders Ephemeroptera, Plecoptera, or Trichoptera. Pipe Creek invertebrates constitute a robust community living in a stressful environment. Significant differences in the abundance of organisms, the number of taxa or their diversity, as measured by Shannon's Index, were not observed downstream from B146. However, the number of taxa and the abundance of subdominant taxa were observed to decline under the bridge and at the +6.0' stations where exceedances of the PEL were observed. These subtle effects were further substantiated using Principle components Analysis. However, it was emphasized that the observed differences in biological endpoints were very small and not statistically significant. The observations could have been simply the result of random sampling. Ten-day sediment bioassays using the amphipod *Hyalella azteca* did not reveal significant differences in survival in sediments from stations located under or downstream from the bridge when compared with those located upstream or with laboratory control sediments.

Commonwealth Edison Railway Right-of-Way Studies. Hines Emerald Dragonfly (*Somatochlora hineana*) is an endangered species inhabiting the Des Plaines River Wetland in Will County, Illinois. In 1996, the U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers required PAH monitoring in wetlands adjacent to Commonwealth Edison's spur line crossing this area. Brooks (1997b and c) reported the results of PAH sampling in wetland sediments at upstream reference stations and at distances of 0.0, 0.5, 3.0, 5.0 and 30.0 meters downstream from the toe of the railway ballast (crushed limestone). Four of the 35 samples collected at 0.0 meters from the ballast exceeded 7.0 μg TPAH/g dry sediment weight and two of these samples exceeded 10 μg/g (21 and 23 μg/g). The suite of PAH in creosote is dominated by intermediate weight PAH compounds. The four high samples were dominated by heavier four through seven ring PAH, suggesting that the source was either old and highly weathered creosote or some other material such as coal or crankcase oil. It was not possible to determine the source of the four high PAH samples. However, it should be noted that all other downstream samples contained lower concentrations of PAH (0.045 ± 0.095 to 0.278 ± 0.134) than were found in the upstream control (0.833 ± 0.520). The point being that there was surprisingly little PAH contamination associated with this right-of-way, which is used primarily to carry coal into the power plant.

To further investigate the contribution of creosote derived polycyclic aromatic hydrocarbons from treated railway ties to adjacent wetland sediments and stormwater, Commonwealth Edison and the Railway Tie Association undertook a highly controlled mesocosm study in 1998 (Brooks 1999a). Three wetland mesocosms were constructed in April and May of 1998 to assess the migration of creosote preservative from new and used railway crossties into right-of-way ballast, ground water, storm water, and adjacent wetland soils. The mesocosms were designed and constructed to closely mimic the commonwealth Edison railway right-of-way in the Des Plaines River wetland. One mesocosm was constructed using untreated hardwood ties. A second mesocosm used newly treated ties and the third was devoted to an examination of weathered ties.

Baseline wetland soil, ballast and water samples indicated that construction was accomplished without significantly contaminating the mesocosms with polycyclic aromatic hydrocarbons. Mesocosm wetland soils were obtained from the Des Plaines River Wetland. Wetland hydrology was maintained during the summer of 1998 using a subsurface irrigation system. Volunteer wetland plants became established in all three mesocosms by the end of the first summer of study. Crushed limestone ballast, wetland sediments and stormwater were monitored quarterly for PAH.

Elevated concentrations of polycyclic aromatic hydrocarbons were observed at low levels in railway right-of-way ballast within ten days of installing the ties. Concentrations of PAH peaked in both the weathered tie and new tie mesocosms during August of 1998. The suite of PAH in these ballast samples was rich in intermediate weight PAH characteristic of creosote oil. Higher concentrations were observed in ballast rock adjacent to the new ties than were observed adjacent to the weathered ties.

One ballast sample from the untreated tie mesocosm (where there were no sources of PAH) contained high levels of PAH on August 18, 1998. Elevated concentrations of PAH were not observed in ballast adjacent to the untreated ties at any other time. There is no source of PAH in the untreated tie mesocosm. This example points out the need for caution in assuming a cause and effect relationship based on one or two samples containing elevated concentrations of PAH. Concentrations of PAH declined significantly in ballast supporting both weathered and newly treated ties between August and November of 1998. This was likely due to weathering (chemical and photo-oxidation).

Wetland sediments in the weathered tie mesocosm revealed slightly elevated levels of PAH on both May 28 and August 28, 1998. However, the PAH suite in the samples did not include the intermediate weight compounds characteristic of creosote (phenanthrene through fluoranthene). Instead, these samples contained primarily high molecular weight compounds characteristic of aged creosote (one or more years outside the treated wood) or with another source. Elevated levels of PAH were not observed in sediments adjacent to ballast supporting either untreated railway ties or those newly treated with creosote. Polycyclic aromatic hydrocarbons were not detected in any stormwater sample.

During 1998, PAH concentrations peaked in the summer and declined in the fall. This may be due to summer heating of creosote, particularly in newly treated ties. The ties act as black bodies and very high temperatures may occur on exposed surfaces. This may cause creosote blisters to form. When these blisters rupture, tiny particles of creosote oil may be projected to distances of up to 30 cm from the source. This hypothesis is consistent with observations from other current studies of the environmental effects associated with creosote treated wood (Goyette and Brooks, 1999; Brooks 1999b). This hypothesis, which is currently under investigation, is called the *particulate PAH transport hypothesis.* It is further suspected that these microspheres, or particles of PAH, remain intact and that they adhere to many solid surfaces, like right-of-way ballast. This would explain their very patchy distribution around creosote treated wood and the very short distances at which they were observed. For instance, EPRI (1997) reported that creosote concentrations in soils at the base of utility poles declines exponentially with most of the PAH found within 3 inches of the pole and very little found beyond 8 inches.

At the end of the first six months of this two year railway tie study, it was apparent that small amounts of polycyclic aromatic hydrocarbons did migrate from creosote treated railway ties into adjacent crushed rock ballast. However, it appeared that the PAH remain in the ballast and the evidence indicated that PAH did not dissolve in storm water and did not migrate from the ballast into adjacent wetlands. This study is continuing in 1999 and a final report will be available early in 2000.

Summary. Creosote and other preservatives used to extend the life of wood in harsh environments have been used for at least 165 years. It is remarkable that there is no published literature documenting a loss in biological integrity associated with the proper use of these products. Several studies have been undertaken in the last four years to better predict and understand the environmental risks associated with the use of these products. Several of these studies apply directly or indirectly to the use of creosote treated wood in railway transportation systems. The results of this research to date indicate the following:

- Small amounts of PAH are lost from creosote treated wood. The PAH associated with creosote are hydrophobic and do not dissolve in the water column at concentrations that are stressful to plants and animals.

- PAH loss rates from creosote treated wood decline exponentially with time and are less than 10% of the initial loss rates by the middle of the expected life of a typical project.

- Creosote does accumulate in soils and sediments under and around creosote treated wood. Creosote derived PAH appears tightly bound to soil and organic matter. In upland environments it appears that PAH remain within 15 to 30 cm of the pressure treated wood structure.

- PAH lost from new and weathered railway ties do migrate from the wood into ballast. However, preliminary results suggest that railway tie derived PAH do not migrate out of the ballast into adjacent landscapes. It also appears that creosote derived PAH do not migrate from railway rights-of-way in stormwater.

- PAH lost from creosote treated wood is catabolized by a variety of microbes and they are mineralized by chemical and photo-degradative processes. In warm climates, this may lead to a seasonal cycle of PAH concentrations in adjacent soil or ballast, with higher concentrations associated with warm summer temperatures and lower concentrations found in winter when degradative processes exceed losses associated with solar heating.

- The low molecular weight PAH are more labile to microbial degradation. In addition they evaporate more readily and are slightly more soluble in water than are the heavier weight compounds (> fluoranthene). The result is that there is a shift in the suite of PAH to favor the heavier weight compounds as creosote “weathers” in natural environments. It should be emphasized that the four through seven ring compounds are refractive to microbial degradation in anaerobic environments where they can accumulate to toxic levels.

- When creosote treated wood is used in association with aquatic environments, PAH will likely accumulate in sediments in the immediate vicinity of the structures. In aerobic environments, these levels will peak at about three years (Brooks, 1997a) and then decline as microbial degradation exceeds the supply of new PAH lost from the wood.

- Small changes in the aquatic invertebrate community associated with creosote treated structures have been documented. However, these changes have not been statistically significant. In all cases studied to date, the use of creosote treated wood, even in massive bridge structures, has not significantly compromised biological integrity.

- Brooks (1997a) has provided a field verified computer model that appears somewhat conservative from the environments point of view. The CREORISK model is intended as a tool to enable project proponents and permit writers to effectively manage the use of creosote in aquatic environments and to identify those projects where an alternative material should be used.

Preliminary findings from the Commonwealth Edison study suggests that creosote lost from treated crossties and switchties will remain in right-of-way ballast where they pose minimal risk to adjacent landscapes and organisms. Creosote treated wood used in railway bridge construction should be managed to insure that adjacent aquatic resources are not jeopardized. The substantial creosote treated bridges examined by Brooks (1999b) did not compromise local biological integrity. However, there are isolated environments where creosote treated wood may pose significant risk. Computer models are available to identify and manage these projects.

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