RTA TieReport #7

Migration of polycyclic aromatic hydrocarbons from railway ties into wetlands

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BACKGROUND

In 1996, Commonwealth Edison Company replaced unserviceable creosote-treated railway ties supporting a 45-year-old spur line serving a coal-fired power plant in Will County, Illinois. The line runs through the Des Plaines River wetland, which is home to the Hine's emerald dragonfly, an endangered species. The U.S. Fish and Wildlife Service expressed concern that polycyclic aromatic hydrocarbons (PAH) would migrate from the railway ties into the wetland in amounts sufficient to adversely affect the dragonfly.

What PAH concentrations would be of concern?

Creosote is a distillate of coal tar containing about 85% PAH. This family of compounds is created by the incomplete combustion of organic matter. They are ubiquitous in all environments. Common sources include electrical power generation, asphalt paving, vehicle exhaust, forest fires, home heating using wood,etc. They can enter the environment via direct input such as dripping automotive crankcases and oil spills. Bradley et al. (1994) reported mean PAH concentrations of 21.9 ppm alongside roadways in the U.S. cities of Boston, Providence and Springfield. The source of these PAH is most likely automobile exhaust, crankcase oil, abraded tire particles, asphalt, etc. Urban areas away from pavement had concentrations of 8.3 ppm. Similarly, Wild and Jones (1995) reported that urban soils in the United Kingdom contained 4.2 ppm PAH and forest soils 4.8 ppm. Atmospheric deposition of PAH-laden smoke particles and molecules of evaporated PAH are the sources of these widespread background concentrations.

Polycyclic aromatic hydrocarbons have been present on earth since there was life and plants and animals have evolved physiological adaptations that break them down and/or eliminate them. The breakdown products of high molecular weight PAH can be carcinogenic and at high concentrations PAH can be acutely toxic. Based on a literature review, Brooks (1996) concluded that dragonflies are not among the more sensitive animals to PAH.

All PAH are hydrophobic and they bind to other organic compounds and inorganic particulates reducing their bioavailability to living organisms. Sediment quality criteria for PAH are therefore tied to the organic carbon in sediments. Higher PAH concentrations are allowed with increasing sediment carbon. Sediments in the Des Plaines River wetland are organically rich with measured total organic carbon (TOC) concentrations of 11.91%. Numerical criteria have been proposed for the U.S. EPA for three of the 16 priority pollutant PAH and the sum of these three at 11.91% TOC is 110.8 parts per million (ppm) on a dry sediment basis. Criteria for the other 13 PAH have not been proposed by EPA. Washington State (WDOE, 2002) is in the process of developing freshwater sediment standards and has defined a Consensus-Based Standard described as a Probable Effects Concentration above which there is a demonstrated increase in toxicity associated with increasing concentrations of contaminants. For Total PAH (TPAH), this standard is 23 ppm dry sediment (not normalized to TOC). The Consensus Sediment Quality Benchmark recommended by Swartz (1999) for the 13 included PAH has been chosen for evaluating biological responses in this study. At 11.9% TOC, this benchmark is 46.8 ppm PAH.

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What concentrations of PAH were observed in the wetland?

Brooks (1996) examined PAH concentrations in sections of the track supported by 45-year-old ties and sections where unserviceable ties had been replaced with new ties. Three transects were examined in each of these treatments at distances of 0.25, 0.50 and 1.0 meter from the track's ballast and compared with 8 samples collected at wetland reference locations. No PAH were observed at 15 of the 18 samples collected near the railway ballast. However, one of three transects adjacent to the old tie section showed moderate contamination of 13 to 14 ppm PAH at 0.25 and 0.50 meter (10 and 20 inches from the ballast). A single sample, collected 10 inches from the ballast adjacent to the new tie section, contained 5.1 ppm PAH.

Requirement for further studies.

Based on the unknown effects of PAH on Hine's emerald dragonfly, and the fact that 3 of the 18 samples had slightly elevated concentrations of PAH, the U.S. Fish and Wildlife Service requested that creosote-treated ties not be used where the spur crosses habitat used by the dragonfly. The U.S. Army Corps of Engineers (USACE) conditioned Commonwealth Edison's 404 permit to require the use of untreated railway ties and required a study, to be completed within five years, to examine PAH migration from used creosote-treated railway ties into adjacent wetlands.

THE RAILWAY TIE MESOCOSM STUDY

The study required by the USACE was undertaken in 1998 and completed in 2000 using protocols approved by the U.S. Fish and Wildlife Service including strict quality assurance requirements. The study created a mesocosm wetland in May of 1998 that mimicked the area where the railway passes through the Des Plaines wetland. This included lining of three excavations with impermeable surfaces; providing a subsurface source of water to mimic the wetland's hydrology; placement of wetland soils from the Des Plaines wetland; and placement of three sections of railway ties on ballast constructed in a manner identical to the actual line (Figure 1). The three treatments included a section of old ties, a second section of new ties and a third section with untreated oak ties. Each of the sections was isolated from the others and great care was taken to prevent contamination during construction and sampling. Wetland hydrology and soils created an environment in which a rich wetland plant community developed in areas outside the ballast (Figure 1).

Figure 1: *Railway tie study mesocosm as it appeared in November 1998. Three treatments included new and used creosote-treated railway ties plus untreated control ties. The vegetation community growing within the constructed wetland area adjacent to the ballast is dominated by wetland species.*

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Migration of creosote into the limestone ballast.

Samples of the limestone ballast were collected prior to placement of the ties (baseline); ten days following placement; and quarterly thereafter until November of 1999. Ballast was evaluated at distances of 5 cm (2 inches), 20 cm (8 inches) and 30 cm (12 inches) from the faces of each of the three ties in each mesocosm. Little PAH was observed in ballast ten days after placing the ties. However, in August of 1998, ballast PAH concentrations were 1,052 ± 773 ppm at distances < 8 inches from the new ties. As seen in Table 1, ballast PAH declined significantly during the fall and early winter. The downward trend continued through winter and all samples were <1.0 ppm at the end of May 1999 (371 days post-construction). Ballast PAH concentrations remained <1.0 ppm during the second summer of sampling and in the final samples collected on November 24, 1999 after 555 days of study. At the end of the study (Day 555), core samples were retrieved from the ballast at 10 cm intervals to a depth of 80 cm. Ballast PAH concentrations were <1.0 ppm at all depths with no indication of any downward PAH migration. These results show that creosote migrated from newly treated railway ties during the first summer of exposure, but that concentrations declined quickly in fall. A similar increase was not observed from the weathered ties – nor was it observed from the newly treated ties in their second summer.

Table 1: *Concentrations of polycyclic aromatic hydrocarbons observed in railway right-of-way ballast at distances of five, 20 and 30 cm from new creosote-treated railway ties and untreated ties on November 18, 1998, 184 days following tie placement. All values are in micrograms total PAH/g dry sediment (ppm). The detection limit was used as a minimum value for each compound.*

Date	Matrix	Mesocosm	Distance	Mean TPAH	STDEV	95% Confidence
11/18/98	Ballast	Untreated	5	0.661	1.145	1.295
11/18/98	Ballast	Untreated	20	0.000	0.000	0.000
11/18/98	Ballast	Untreated	30	0.000	0.000	0.000
11/18/98	Ballast	New	5	54.561	80.740	91.364
11/18/98	Ballast	New	20	32.928	50.529	57.178
11/18/98	Ballast	New	30	8.782	3.218	3.641
11/18/98	Ballast	Weathered	5	1.082	1.874	2.121
11/18/98	Ballast	Weathered	20	0.088	0.152	0.172
11/18/98	Ballast	Weathered	30	1.489	2.578	2.918

Migration of PAH from ballast into wetland sediments.

Limestone ballast does not provide habitat for plants or animals and the real concern is for PAH that might migrate from the ballast into adjacent wetland areas that support numerous species. Triplicate wetland sediment samples were collected at distances of 0, 25, 50 and 75 cm from the edge of the ballast in each treatment and analyzed for 16 parental PAH on each sampling day. Figure 2 summarizes the total concentration of PAH in wetland sediments. Highest mean concentrations of 4.2 ppm were observed in the untreated tie treatment on 5/24/1999. One sample from the new tie treatment contained 3.95 ppm on day 463 and a single sample from the weathered tie mesocosm contained 3.4 ppm on day 555. It should be noted that all of these values include the sum of the detection limits for the 16 compounds (0.64 ppm). The presence of the highest concentrations in the untreated tie mesocosm suggests a potential for accidental contamination despite the use of gloves and booties dedicated to each treatment on each sampling day. These results indicate that creosote-derived PAH can migrate from ballast to adjacent wetlands but that the resulting concentrations will rarely exceed 2 ppm and the resulting concentrations were not statistically significantly different as a function of distance, treatment or day of sample collection.

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Figure II: Categorized Plot for Variable: MEANTPAH

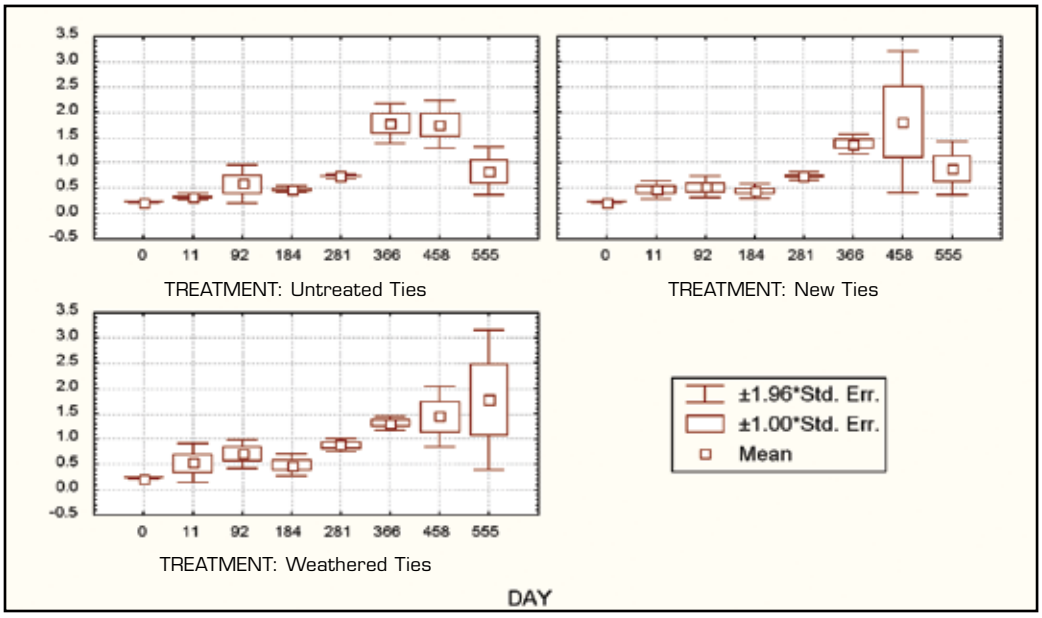

Figure II: *Box and whisker plots describing the significant (Anova, p = 0.000) differences in mean ΣPAH concentrations in sediments as a function of time following placement of untreated oak ties and newly treated or weathered oak ties preserved with creosote.*

PAH in stormwater.

Surface water was collected from each mesocosm on seven sampling dates. Polycyclic aromatic hydrocarbons were not detected in any of these samples on any date excepting the final sample when nanogram/L quantities of PAH were detected in all three mesocosms. The toxicity of these samples was assessed using the sum of toxic units method described by Swartz et al. (1995), who recommended a sum of toxic units (ΣTU) benchmark of 0.186 as protective of all aquatic resources exposed to waterborne PAH. The November 1999 results indicated a ΣTU = 0.059 for the untreated ties; 0.075 for the new ties; and 0.104 for the weathered ties – suggesting no potential toxicity.

Biological assessment.

The low concentrations of PAH observed in stormwater on the last day of the study did not approach the ΣTU benchmark proposed by Swartz et al. (1995) and no adverse effects can be anticipated in association with this route of exposure. Of the 234 sediment samples analyzed in this study, 142 had PAH concentrations <1.0 ppm and only two samples exceeded 4.0 ppm. None of the samples exceeded the Swartz (1999) benchmark of 46.8 ppm in 11.9% TOC sediments. The two samples higher than 4.0 ppm were chosen for an evaluation of the toxicity of individual compounds. One of the samples was from the weathered tie mesocosm (6.26 ppm) and the other from the newly treated tie mesocosm (9.83 ppm). The results of computing the sum of toxic units at the mean sediment TOC for each compound showed that no individual PAH or their sum exceeded the toxic unit threshold below which no effects can be anticipated in any species. The ΣTU for the 6.26 ppm weathered tie sample was 0.122 and it was 0.198 for the new tie sample. Both values are less than 20% of the benchmark ΣTU = 1.0. Also note that none of the samples approached any of the previously described regulatory benchmarks for PAH. These results indicate that the small amounts of PAH observed migrating from the railway ballast into the adjacent wetland posed no threat to any living organism.

SUMMARY AND CONCLUSIONS

Brooks (1996) assessed the potential impact of this railway right of way on Hine's emerald dragonfly (*Somatochlora hineana*) and concluded that, based on the limited data available at that time, "There was no indication that the past use of creosote ties, or their current replacement (new ties) had compromised the biological integrity of wetland plants or animals, including *Somatochlora hineana*. The completion of the River South PAH study (Brooks, 1997) and these results have added significantly to the database upon which the biological effects associated with creosote-treated railway ties can be evaluated. The following conclusions are substantiated by the results presented in these reports:

- Small amounts of creosote-derived PAH will likely migrate from newly treated railway crossties into supporting ballast during the summer of the first year. In this study, this pulse was not observed during the second summer. Site-specific behaviors will depend on the wood species, creosote retention, solar insolation and ambient air temperatures.

- Significant quantities of PAH did not migrate downward into the railway ballast.

- Based on PAH concentrations observed in the untreated tie treatment, it appears that atmospheric deposition of PAH contributes much of the observed background to Des Plaines River wetland sediments.

- Small amounts of PAH migrated from the ballast into adjacent wetlands during the summer of the second year of study. The PAH spectrum in these samples and a comparison of PAH concentrations in the untreated mesocosm with the creosote treatments suggests that ~0.3 ppm of this loading was associated with creosote. The observed increases were not statistically significant as a function of distance, treatment or day of the study.

- PAH were detected in one of 16 water samples.Those samples were collected on the final day of the study. The detected PAH concentrations were very low and an assessment using the sum of toxic units described by Swartz et al. (1995) indicated that none of the samples approached the benchmark recommended by those authors for the protection of aquatic life.

- The PAH concentrations observed in the highest sediment samples collected in the new and weathered tie mesocosms are not predicted to be toxic using the consensus sediment benchmark methodology of Swartz (1999) and no adverse biological effects can reasonably be predicted in association with the use of new or weathered railway ties in this environment.

There are many sources of PAH associated with railway transportation systems. These include diesel exhaust, lubricating oils, cargo (coal and oil) and herbicides. A mesocosm study was designed to minimize these confounding sources of PAH and to focus on those PAH associated with creosote-treated railway ties. These results suggest that seasonally variable atmospheric deposition of PAH contributes a significant portion of the background observed throughout the Des Plaines River wetland. It also appears that on average, the use of creosote-treated railway ties may add an additional 0.3 ppm PAH within half a meter of the toe of railway ballast.

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