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Technical Memorandum
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Summary of McIntyre et al. 2016. “Severe Coal Tar Sealcoat Runoff Toxicity to Fish Is Prevented by Bioretention Filtration” Environ. Sci. Technol. 50:1570−1578

Summary

- The Zebrafish embryo tests selected for this study were chosen because of their sensitivity to PAHs.
- The toxicity of artificial runoff from an RTS test plot decreased between day 1 and day 7 but remained relatively constant between day 2 and day 207.
- The toxicity of test plot runoff was consistent with samples of highway runoff collected from an area unlikely to be influenced by coal tar sealcoat (i.e., refined tar sealer or RTS).
- A model bioretention system, consisting of a 60-cm layer of a sand-compost mixture, eliminated toxicity for all but the most sensitive biological indicators. Bioretention treatment reduced the response of the sensitive indicators.
- Bioretention treatment reduced PAH concentrations by >95%.

Project Goals

The goals of this study were to:

1. Characterize lethal and sublethal aquatic toxicity effects of runoff from a refined tar sealant (RTS) treated test plot.
2. Evaluate the ability of soil bioretention treatment to reduce the toxicity of the runoff.

Use of soil bioretention systems to treat stormwater is the research focus of the team that conducted the research. This is their first project looking at RTS.

Methods

A 110-m^2 RTS test plot was set up within a parking lot at the research facility at the University of Washington-Puyallup. A second plot was created with an asphalt based sealer. Artificial runoff was generated by using a sprinkler system to create 0.40-cm rain events (300 l added at 0.25 cm/m^2 hr). Based on the manufacturer's suggested "drying time" of 2hr, the first sampling event was started 2hr (0.08 days) after application. Three additional sampling events were conducted at day 7, 13, and 207. The soil bioretention systems consisted of 36-cm-diameter columns filled to a depth of 60 cm with a 60% sand / 40% compost mixture.

Toxicity tests were conducted on the runoff as collected and bioretention treated runoff. Runoff from the asphalt test plot was only tested untreated by a bioretention system. Chemical analysis included 25 PAHs consisting of the EPA 16 priority pollutants, 8 alkylated PAHs, and dibenzothiophene. The toxicity tests consisted of:

	Juvenile Coho Salmon	**Zebrafish Embryo**
Toxicity		
Survival	96 hr	48 hr
Sublethal Toxicity		
Cardiac Development	-	48 hr
Cranial Development	-	48 hr
Molecular Indicators		
P450 (chemical exposure)	-	48 hr
Cardiac Stress	-	48 hr

Zebrafish embryos were selected as a test system because of their sensitivity to chemical exposure, known patterns of resulting defects, and the ability to survive over the 48 hr test period with developmental abnormalities. Salmon were used because of their local importance.

Results

Key results are summarized in the following tables.

Table 1: Total PAH_{25}, naphthalene, and phenanthrene concentrations (ug/l) of untreated and bioretention (BR) treated runoff of the RTS test plot.

Event	Time (days)	tPAH	BR tPAH	Nap	BR Nap	Phen	BR Phen
1	0.08	1310	4	227	0.05	306	0.60
2	7	148	0.4	3.1	0.05	46	0.05
3	13	175	0.6	1.8	0.19	46	0.20
4	207	153	0.2	3.4	0.03	53	0.04

Table 2: Toxicity test results of untreated and bioretention (BR) treated RTS test plot runoff.

Event	Coho Survival	BR Coho Survival	ZF Embryo Survival	LD 50	BR ZF Embryo Survival
1	0%	100%	0%	34%	100%
2	20%	100%	100%	-	100%
3	10%	100%	100%	-	100%
4	55%	100%	100%	-	100%

Table 3: Sublethal test results for untreated and bioretention (BR) treated RTS test plot runoff.

Event	Sublethal Toxicity min dilution tested	Sublethal Effects	BR Sublethal Effects at 100%	Molecular Indicators Response	BR Molecular Indicators Response
1	12%	Y	Minor	Y	Low
2	100%	Y	N	Y	Low
3	100%	Y	N	Y	Low
4	100%	Y	N	Y	Low

The total PAH and phenanthrene concentrations dropped about 90% between the first day and the sampling event at day 7, while the naphthalene concentrations dropped about 99%. Phenanthrene was highlighted because the authors indicated that prior research has shown it to be a key trigger of toxicity to Zebrafish embryos. Bioretention treatment resulted in a >99% reduction in PAH concentrations.

Event 1 runoff was the only sample that resulted in 100% mortality of Coho salmon. The survival in runoff collected at the three sampling events ranged from 10 to 55%. Survival rates were not proportional to the PAH concentrations for the three later events.

No embryos survived for 48 hrs in untreated runoff from Event 1. The calculated LD50 was 34%. Sublethal effects were noted at 12% runoff, the lowest concentration tested. There was 100% survival of embryos in untreated runoff from the other three events, but the expected sublethal effects were detected. The dominance of specific effects differed among the events. Bioretention treatment eliminated lethal effects for all events, and sublethal effects in all but the first event. It also significantly reduced the response of the molecular indicators.

Discussion

The Zebrafish tests were selected because they are known to be very sensitive to PAHs and other contaminants. Research team member JP Incardona has published a series of papers on using these assays to evaluate low levels of PAHs following oil spills. Any relationship between laboratory test results and real world effects is uncertain.

McIntrye's research team has conducted similar toxicity and bioretention treatment tests on stormwater highway runoff collected in Seattle, WA (McIntyre et al 2014; 2016b). Waters from six events collected throughout the year were tested. PAH_{16} concentrations ranged from 2 to 22 ug/l, with all but one having a concentration less than 11 ug/l. Two of the stormwaters killed all Zebrafish embryos in 96 hr tests, and a third sample resulted in a significant reduction in survival. All six of the stormwaters caused sublethal effects. Toxic effects were reduced or eliminated by bioretention treatment. Coho survival tests were conducted with highway runoff from one of the sampling events. Toxicity was noted in untreated stormwater but not in the bioretention treated samples.

RTS Event 1 runoff had results similar to two of six real world highway runoffs as none of the Zebrafish embryos survived. The other events were similar to a third highway runoff event in terms of reduced embryo survival. Both RTS runoff and highway stormwater runoff resulted in sublethal effects in surviving embryos. Toxic effects were noted even though the reported total PAH concentrations in the stormwaters were lower than RTS test plot runoffs. Some of the difference in total concentrations is attributable to the number of compounds analyzed.

Results for Events 2, 3, and 4 were generally similar. While Event 1 runoff was more toxic, the collection time of 2 hrs post RTS application is shorter than the more typical recommendation of at least 24 hrs between application and possible rain. There was a 90% reduction in tPAH and 99% reduction in naphthalene over the first week.

While McIntyre et al. 2016 is apparently the team's first evaluation of parking lot runoff, others have shown it to be toxic in the absence of RTS. Greenstein et al 2004 tested artificial runoff from an operating asphalt parking lot in Southern California. Using a sensitive marine aquatic bioassay, sea urchin egg fertilization, toxicity was noted in all runoff samples. A toxicity identification evaluation suggested that organic compounds and zinc were potential toxicants. Toxicity was not correlated with total PAH concentration, which did not exceed 30 ug/l.

Comments

This study is similar to other research conducted by this team. While RTS test plot runoff is the material being tested, the primary purpose is to demonstrate the benefits of soil retention as a stormwater treatment technology. Prior work by the same authors has shown the sensitivity of Zebrafish embryo bioassays to PAHs and potentially other constituents in stormwater and the ability of their bioretention test system to reduce the toxicity of runoff from several types of paved surface.

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References

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