High Performance Bioretention Soil Mixes: An Effective Tool for Treating 6PPD-quinone in Stormwater

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What is 6PPD-quinone (6PPD-q)? Science

- Recently discovered tire chemical (Tian et al. 2021)
- Cause of widespread death of coho salmon spawning in urban streams
 - Urban Runoff Mortality Syndrome

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A ubiquitous tire rubber-derived chemical induces acute mortality in coho salmon



REPORT



What is 6PPD-quinone?

- Recently discovered tire chemical
- Cause of widespread death of coho salmon spawning in urban streams
- Also toxic to other salmonids in King County at concentrations measured in surface waters





Table 1. Reported 6PPD-quinone LC₅₀ concentrations (50% observed mortality) of salmonids.

Species	LC ₅₀ (μg/L)	Test duration (h)	Toxicity Key	
Coho salmon (Oncorhynchus kisutch)	0.04, ²⁴ 0.08, ²⁵ 0.095 ²	24	Higher	
White-spotted char (Salvelinus leucomaenis pluvius)	0.51 ²⁶	24		
Brook trout (Salvelinus fontinalis)	0.59 ³	24		
Rainbow trout/steelhead (Oncorhynchus mykiss)	0.64, ²⁹ 1.0, ³ 2.26 ⁵	96		
Chinook salmon (Oncorhynchus tshawytscha)	67.3 ²⁴ , 82.1 ²⁵	24		
Sockeye salmon (Oncorhynchus nerka)	Not acutely toxic at 50 ²⁵	24	Lower	
Atlantic salmon (Salmo salar)	Not acutely toxic at 12.2 ²⁸	48		
Brown trout (Salmo trutta)	Not acutely toxic at 12.2 ²⁸	48		
Arctic char (Salvelinus alpinus)	Not acutely toxic at 12.7 ³	24		

Interstate Technology Regulatory Council, 2023

How toxic is 6PPD-q to coho?

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Table 1. Comparison of the Toxicity of 6PPD-Q to Coho Salmon with Those of the Most Toxic Chemicals for Which the U.S. Environmental Protection Agency Has Established Aquatic Life Criteria^a

chemical class	name	most sensitive species	LC ₅₀ (ppb)	95% CI	ref	CMC (ppb)	EPA document
OP	parathion	Orconectes nais	0.04	0.01-0.2	25	0.065	EPA 440/5-86-007
quinone	6PPD-Q	O. kisutch	0.10	0.08-0.11	this study	not available	not available
OC	mirex	Procambaris blandingi	0.10	not reported	26	0.001	EPA 440/5-86-001
OP	guthion	Gammarus fasciatus	0.10	0.073-0.014	25	0.01	EPA 440/5-86-001
OP	chlorpyrifos	Gammarus lacustris	0.11	not reported	27	0.083	EPA 440/5-86-005
OC	endrin	Perca flavescens	0.15	0.12-0.18	28	0.086	EPA 820-B-96-001
OC	4,4'-DDT	O. nais	0.18	0.12-0.30	25	1.1	EPA 440/5-80-038
OP	diazinon	Ceriodaphia dubia	0.25	not reported	29	0.17	EPA-822-R-05-006
metal	cadmium	Oncorhynchus mykiss	0.35	not reported	30	1.8	EPA-820-R-16-002
OC	methoxychlor	O. nais	0.50	0.25-1.8	25	0.03	EPA 440/5-86-001
OC	dieldrin	Pteronarcella badia	0.50	0.37-0.67	28	0.24	EPA 820-B-96-001
OP	malathion	G. fasciatus	0.76	0.63-0.92	25	0.1	EPA 440/5-86-001
OC	toxaphene	Ictalurus punctatus	0.8	0.5-1.2	31	0.73	EPA 440/5-86-006

^{*a*}The rationale for the toxicity comparison can be found in SI text. Abbreviations: OP, organophosphate; OC, organochlorine; CMC, criterion maximum concentration; CI, confidence interval.

Tian et al. 2022. 6PPD-Quinone: Revised Toxicity Assessment and Quantification with a Commercial Standard. *Environ Sci Tech Letters*



Impetus for this study

- Need to identify stormwater treatments for 6PPD-q
- Bioretention (sand and compost) protects coho¹ and removes 6PPD-q² from stormwater
- King County has adopted high performance bioretention soil mixes (HPBSMs) for water quality treatment
 - Limit nutrient and metals export

Question: Is HPBSM effective at treating 6PPD-q and protecting coho salmon from stormwater runoff?







Bioretention soil mixes (BSMs)



Suspended solids treatment $(\geq 80\%$ reduction)



¹⁵ **P**

Dissolved metals treatment (≥ 30% Cu, ≥60% Zn reduction)

Phosphorus treatment Phosphorus 30.973 $(\geq 50\%$ reduction)



Supports plant growth



Methods - stormwater collection



Methods



WWU student researchers sampling treated effluents Credit: Curtis Hinman

- Dosed columns of BSM with I-5 runoff to simulate 3 storm events
 - 60% sand:40% compost BSM
 - HPBSM Type 1
 - HPBSM Type 2
 - HPBSM Type 3

High performance bioretention soil media mixes

- KCEL tested stormwater and bioretention effluent for 6PPD-q and toxicity to juvenile coho salmon
 - Excluded HPBSM type 2





Untreated

Treated

I-5 Stormwater runoff 60:40 BSM F

HPBSM type 1 HPBSM type 2

11 14

HPBSM type 3

Bioretention medias prevent coho mortality





Treated bioretention effluents

Bioretention medias prevent coho mortality



100% coho exposed to treated bioretention effluents survived



Treated bioretention effluents

High 6PPD-q removal rates by mixes



o >96% 6PPD-q removal by all medias

High 6PPD-q removal rates by mixes



 HPBSMs provided small but significant improvements in 6PPD-q treatment

Bioretention media

Type 2

Type 3

* p ≤ 0.05 **p ≤ 0.01

Type 1

BSM

6PPD-q concentrations in treated effluents



Values below the detection limit were substituted with 0.

Take home points

HPBSMs removed nearly all 6PPD-q from stormwater.

Filtering stormwater through bioretention media protected coho from 6PPD-q.

HPBSMs treat many toxic chemicals - more than just 6PPD-q!

scale.

Next, we are testing 6PPD-q and PFAS treatment by HPBSM at full

Thank you!

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Curtis Hinman & Associates



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Questions?





My contact info!