



Study Highlights

- Contaminant removal and salmon survival persistent across 13 simulated treatment years.
- Shallower bioretention media performed nearly as well as deeper media.

Goal & Background

Urbanization poses increasing threats to aquatic ecosystems, including increased chemical loading. The impacts of urbanization on biological integrity are especially evident in the lowland, urban streams of western North America, where adult coho salmon (*Oncorhynchus kisutch*) returning to spawn in the fall have been prematurely dying at high rates. Previous studies have demonstrated the effectiveness of bioretention treatment systems in treating urban stormwater runoff, thereby reducing chemical loading into surface waters and preventing lethal and sublethal effects on aquatic organisms.

The current study aims to determine the effectiveness and longevity of the Washington state 60:40 sand:compost (% by volume) bioretention soil media (BSM) at various infiltration depths, including those shallower than the depth currently required — 18 inches — by the Washington Department of Ecology

Study questions included:

- How long can the 60:40 BSM prevent acute toxicity from urban stormwater?
- What soil depths are necessary to provide sufficient biological protection and water quality treatment?

Experimental columns — containing five different BSM depths — were dosed with roadway runoff at an accelerated rate to simulate 13 water years in approximately four calendar years. The chemical and biological effectiveness of the columns in treating runoff was assessed using analytical chemistry and the health of two fish species: a common laboratory model (zebrafish) and a native salmonid species of concern (coho salmon).

Project Findings

Bioretention treatment efficiently removed total lead, zinc, polycyclic aromatic hydrocarbons (PAHs), and suspended solids (> 90% removal). Total copper (73%), nickel (59%), and arsenic (37%) were more modestly removed in part due to leaching from the organic fraction of the media.

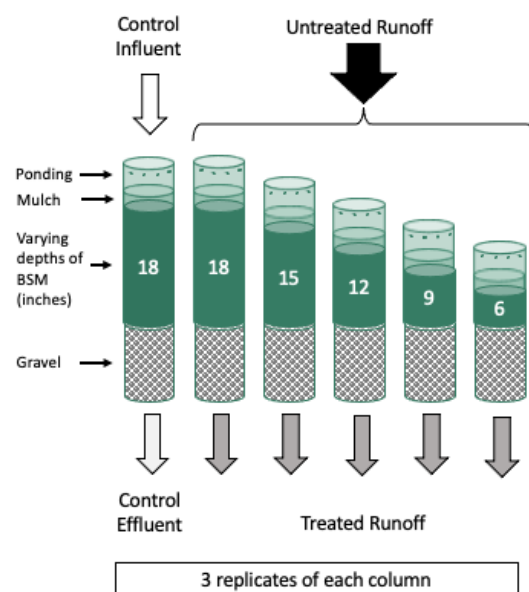


Figure 1. Study Design

Collectively improving stormwater management

Stormwater Action Monitoring (SAM) is a collaborative, regional stormwater monitoring program that is funded by more than 90 Western Washington cities and counties, the ports of Seattle and Tacoma, and the Washington State Department of Transportation. SAM's goal is to improve stormwater management to reduce pollution, improve water quality, and reduce flooding. We do this by measuring stormwater impacts on the environment and evaluating the effectiveness of stormwater management actions.

Dissolved organic carbon and nutrients were generally exported from the BSM. Although all treatments continued to export nutrients after 13 accelerated years, the exports were greatly reduced by the end of the first accelerated year. Across the study, the shallowest media depth (6 inches) released lower concentrations of nutrients, dissolved organic carbon (DOC), total suspended solids (TSS), arsenic, and nickel than the deeper media treatments, but was less effective at capturing copper than the 12-inch or 18-inch depths. Depth did not have an impact on effluent concentrations of total PAHs, zinc, or lead.

We did not see signs that contaminants were breaking through during the 13 accelerated treatment years. Instead, the soil started losing its ability to absorb stormwater around year 7. This was demonstrated by influent water exceeding the ponding depth (3 inches) and also by saturated hydraulic conductivity reduced from >400 cm/hour at study initiation to <100 cm/hour. Surface samples removed at this time showed that the standard bioretention depth of 18 inches retained a higher porosity than the shallower media and also contained lower concentrations of metals and PAHs than the 6-inch depth.

Influent stormwater runoff induced morphometric changes and detoxifying enzymes in zebrafish and was acutely lethal to juvenile coho salmon (56-100% mortality). Bioretention treatment tended to improve morphometric impairment and reduced/prevented induction of *cyp1a*. Bioretention treatment of all depths continued to prevent coho mortality throughout the study, associated with high rates of 6PPD-quinone removal (>90%). Morphometric and molecular indicators of toxicity to zebrafish were improved by bioretention treatment and tended to be more pronounced in the deeper media.

The trade-offs evident in contaminant release from BSM, removal of toxicity, and longevity of hydraulic conductivity between shallower and deeper media suggest that an intermediate depth of media such as 12 inches could be considered in place of the current standard of 18 inches.

Recommendations

These results suggest that shallower bioretention designs may be feasible. If confirmed, this could significantly reduce construction costs, limit contaminant export, and make bioretention suitable for a wider range of sites. However, given that this study is among the few to evaluate long-term performance and relied on accelerated loading, further research, including field testing, is needed to confirm these outcomes across diverse environmental conditions before design guidance is refined.

Why does this study matter?

Untreated stormwater has been found responsible for Coho salmon pre-spawn mortality in streams in our region; stormwater also causes numerous sublethal effects. Bioretention is a promising solution to this problem. Knowing that the required treatment practices are protective of embryos and adult spawners provides confidence in widespread application of bioretention. These results confirm that treating stormwater using bioretention with the standard 60:40 mix minimizes toxic and lethal effects to Coho salmon, except when untreated runoff mixes with the treated effluent in bypass events. Bioretention installation can be costly to install, maintain, and replace. In addition to testing the longevity of the media, this study found that shallower media provides nearly the same level of water quality treatment.

What should stormwater managers do with this information?

Stormwater managers should continue to install bioretention systems as opportunities arise. Permittees should implement Ecology's guidance for applying bioretention treatment to projects in Western Washington. Bioretention treatment with BSM can be incorporated at any scale when planning stormwater retrofit projects. Permittees should encourage developers to include bioretention in all site plans for new development, redevelopment, and retrofit projects where bioretention is feasible.

What will Ecology do with this information?

Ecology's stormwater management manual will continue to specify the 60:40 mix as the standard BSM for bioretention. We will use these findings to guide future research and field testing to confirm the results before refining bioretention design guidance. SAM will continue to support studies to improve BSM and consider cost conscious refinements.

For more information, including the final report, visit the website at

ecology.wa.gov/sam

To request an ADA accommodation, contact Ecology by phone at 360-407-6600 or email at chelsea.morris@ecy.wa.gov, or visit <https://ecology.wa.gov/accessibility>. For Relay Service or TTY call 711 or 877-833-6341.