Roads to Ruin
Will Water Quality Retrofits Save Salmon?

Report to King County WaterWorks Grant Program
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July 2021

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Background

Untreated urban stormwater runoff impairs water quality and is acutely toxic to Coho Salmon (*Oncorhynchus kisutch*) (Scholz et al. 2011, McIntyre et al. 2018, Chow et al. 2019) and other aquatic species (McIntyre et al. 2015). Modeling studies suggest that Coho Salmon mortalities from stormwater runoff contribute to population declines throughout the Puget Sound region (Spromberg & Scholz 2011). Treating runoff through simple biofiltration media can eliminate these toxic effects (McIntyre et al. 2014, Spromberg et al. 2016, McIntyre et al. 2015). However, finding locations to install biofiltration facilities in urban areas can be challenging and expensive. Novel solutions are needed for reducing the impact of stormwater runoff on receiving waters.

Retrofit of existing untreated areas, beyond redevelopment projects, has been suggested as an important next step towards reducing stormwater impacts to Puget Sound. Demonstrating a simple method of implementing stormwater quality treatment retrofits will benefit the natural environment for all aquatic species and enhance the quality of life for all residents well into the future.

Study Purpose

Retrofit an older publicly owned detention pond using biofiltration media and pilot test its performance for improving water quality and preventing toxicity from stormwater runoff.

Methods

Test Site Selection and Description

Site Selection

The City of Bellevue reviewed potential detention ponds that would be suitable to meet the project goals. Initially, several ponds were explored for retrofit opportunities. Ponds of interest were those that had a suitable inflow from a nearby busy arterial, the ability to easily access, as well as perform the necessary modifications, and a suitable area for collecting inflow/outflow before and after treatment.

Influent stormwater to the detention pond was tested for toxicity prior to confirming site selection. A grab sample of influent stormwater runoff at the proposed site was collected as it entered the pond on Oct 5, 2018 and tested for toxicity using the zebrafish (*Danio rerio*) embryo model at Washington State University (Puyallup Research & Extension Center). Toxicity was associated with the influent stormwater sample, including a significant decrease in eye area and heart areas which is consistent with exposure of developing fish embryos to stormwater runoff (McIntyre et al. 2014).

Site Description

A detention pond at 4315 130th PL SE, adjacent to SE Newport Way, was selected for this pilot project. The pond is approximately 2500 square feet during low flow/normal operations with an overflow footprint of approximately 3800 square feet. The pond collects approximately 20 acres of runoff from a single-family neighborhood that includes the arterial, Newport Way, which is listed as a minor arterial in City of Bellevue's Transportation Plan.

Site Modifications

Bellevue Storm & Surface Water staff with direction from the project team prepared the pond by excavating residual sediment from the pond bottom to its original designed depth and excavated two small trenches to allow the BURitos to be keyed in below the pond bottom.

Bioretention Urban Retrofits (BURitos)

BURito Development

The bioretention urban retrofits (BURitos) concept was to use rolls of bioretention media perpendicular to the direction of flow in the detention pond to provide treatment similar to that for gravity-fed bioretention installations. However, we discovered that the standard Washington State specified bioretention media (60% sand + 40% compost, by volume) is too dense to treat runoff flowing laterally. In pilot tests with BURitos filled with bioretention media, water built up behind the roll and eventually flowed over, around, or under the BURitos rather than being filtered through the media.

Chris Cunningham, of Cedar Grove Compositing, generously donated time and materials to help develop a compost-included media that would not impede the lateral hydrology of the detention pond and that we hoped would provide a treatment benefit similar to that of bioretention. Hydrologic performance of the test media was verified with dye tests.

C. Cunningham additionally donated time to assist City of Bellevue staff to install and maintain the BURitos (described below).

BURito Toxicology Screening

For media with the desired hydrologic performance, toxicology screening was conducted to ensure that the media were not releasing contaminants that would be toxic to aquatic life when installed in the detention pond. Triplicate samples of media were secured in the sock material with a zip-tie and soaked in clean water for 5 min. This procedure was repeated 3 times. On the fourth soaking, 250 mL of water from each replicate was filtered through a 63-µm stainless steel sieve and collected in a 1-L glass media bottle. Aliquots of this pooled effluent water were frozen prior to testing toxicity using zebrafish embryos.

An initial set of proposed media containing coarse wood and arborists mulch caused significant mortality of the zebrafish embryos. Raw wood is known to contain chemicals that leach into water and can be acutely lethal to fish; this includes western red cedar (Lalonde et al. 2011) and aspen (Taylor et al. 1996), for example. A subsequent test of media composed of 60% coarse sand and 40% medium compost leached with clean water produced no mortality or sublethal impairments. This media was selected for use in the BURitos. The sand was an unwashed screened utility sand with specifications included as Appendix 1. Specifications for the compost are included as Appendix 2.

BURito Installation

Installation on October 16, 2019 required pond preparation to ensure an accurate runoff sample was collected; the surrounding vegetation was cut back, accumulated sediment from the previous season was excavated, and an access route for the blower sock installation equipment was cleared. A high-density polyethylene (HDPE) sock (VIS Socks; 5 mm; 12” diameter) was laid out, filled in place by Cedar Grove Composting, and the socks were keyed in to secure them from movement or water bypassing beneath or around them. A small collection depression was excavated to provide access for sampling. One set of 3 stacked BURitos was placed at the head of the pond whereas the second set was placed at the tail of the pond.

BURito Maintenance

Maintenance included mowing vegetation around the BURitos, minor grading in front of each BURito to remove built-up sediment, and minor sock repair. Cutting grass around the BURito required care due to their fragile nature. Hand work or careful use of a line trimmer were necessary to prevent damage to the sock. This maintenance and minor grading occurred on September 17, 2020. The mesh of the BURito sock degrades over time from exposure to ambient ultraviolet light so repairs to the sock were necessary on October 1, 2020.

Stormwater Sampling

City of Bellevue staff collected samples at the pond for toxicity testing and quantitative chemical analysis for a suite of parameters. The intent was to collect grab samples at the beginning of a storm event at the inlet to the pond (influent; INF), after the first set of BURitos (BUR1) and after the second set of BURitos (BUR2). A qualifying storm event was considered to be a minimum antecedent dry period of 24 hours.

Table 1. Number of samples for chemistry, toxicology for each sampling location and date

Date	INF	BUR1	BUR2
5/30/20	1,1	1,1	0,1
11/3/20	1,1	1,1	1,1
3/18/21	1,1	1,1	0,0
3/24/21	1,1	1,1	1,1

Sampling staff ran into issues which limited collection at BUR2 for each storm event and limited the number of storms that were sampled (Table 1). One issue was that the pond held water during the wet season. Standing water prevented sampling a qualifying storm because of the goal of ensuring that only water being treated by the BURitos was being sampled. Event 1 and 2 occurred when the pond was already dry (May and November 2020), but for Events 3 and 4 (March 2021) the problem of standing water preventing collection was avoided by pumping out standing water in the pond immediately preceding a storm event. The other issue was rain production. In two of the sampling events, staff could not collect grab samples after the second BURito because the storm had ended before water could reach the second BURito.

For the influent runoff entering the pond, samples were collected from the runoff that was pouring from the storm pipe into the final storm manhole located at the curb line on 130th PL SE at Newport Way. After the first and second BURitos, samples were taken after the stormwater ran through the BURitos. During the first sampling event, water was monitored as it moved through the first BURito, which took approximately 30 minutes. Staff supervised the flow from the inlet pipe through the pond to the BURitos. Samples were collected just as the water was moving through the BURitos. All samples were collected before stormwater overtopped the BURitos. In larger storms, stormwater will eventually overtop the BURitos rather than all pass through the BURitos.

Once samples were collected, they were placed in coolers with ice and transported to either Freemont Analytical (water chemistry) or to a freezer (toxicity samples) to await transport to Washington State University (WSU).

Water Chemistry

Water samples were submitted for chemical analysis to a commercial analytical chemistry laboratory (Fremont Analytical, Seattle, WA). Water was analyzed for a suite of conventional analytes (ammonia, dissolved organic carbon (DOC), total suspended solids (TSS)), metals (dissolved Cu and Zn), nutrients (nitrates (NOx), total phosphorus (TP)), 21 polycyclic aromatic hydrocarbons (PAHs), and six phthalates.

An assessment of chemical data quality is presented in Table 2. Four of the six phthalates were detected in blank samples at or above measured values for field samples and were therefore discarded from further analysis. Among the remaining 31 analytes, 9 PAHs were not detected in any sample, and an additional 10 PAHs were detected in less than 40% of samples. The 12 remaining analytes, detected in 40-100% of samples, were used to summarize the chemical performance of the pond retrofit.

Due to limited sampling sizes at BUR2, statistical analysis of water quality improvement could only be performed for the INF and BUR1 samples. A linear mixed effects model was run for each of the 12 analytes in R (R Core Team 2021) using the *lmer* function in the *lmerTest* package. Event number (1-4) was included as a random variable to account for the influence of different influent concentrations among events on performance. One half the detection limit was substituted for analytes that were not detected in a sample. However, events were excluded on an analyte-specific basis when the influent was below the detection limit. The low number of samples for the study ($n \leq 10$ across locations and events) reduced statistical power, therefore the level of significance for differences between INF and BUR1 was set to $\alpha = 0.1$.

Table 2. Data quality assessment for all water samples (n=10; 4 INF, 4 BUR1, 2 BUR2)

Rejected from analysis			Retained for analysis		
Class	Analyte	Detection	Class	Analyte	Detection
phthalates	diethylphthalate	BC	metal	Cu	100%
	di-n-butyl phthalate	BC		Zn	80%
	butyl benzyl phthalate	BC	conventionals	DOC	100%
	bis(2)ethylhexyl phthalate	BC		Ammonia	50%
PAHs	2-Methylnaphthalene	0%		Nitrates	90%
	2-Chloronaphthalene	0%		Total P	40%
	Acenaphthalene	0%		TSS	90%
	Acenaphthylene	0%	PAHs	Pentachlorophenol	90%
	Anthracene	0%		Benzo(g,h,i)perylene	60%
	Benz(a)anthracene	0%		Pyrene	60%
	Carbazole	0%	phthalates	Di-n-octyl phthalate	40%
	Dibenzofuran	0%		Dimethylphthalate	40%
	Fluorene	0%			
	Dibenz(a,h)anthracene	10%			
	Chrysene	10%			
	Benzo(k)fluoranthene	10%			
	Benzo(b)fluoranthene	10%			
	Phenanthrene	20%			
	Indeno(1,2,3-cd)pyrene	20%			
	Fluoranthene	20%			
	1-Methylnaphthalene	20%			
	Naphthalene	30%			
	Benzo(a)pyrene	30%			

BC = blank contamination

Aquatic Toxicology

Additional water samples were frozen (-20℃) in amber glass bottles for subsequent toxicology screening (Washington State University, Puyallup, WA). Individual zebrafish embryos 2-4 hpf (hours post fertilization) were placed in individual wells of glass-lined 96-well microplates. Thirty-two individuals were exposed to each test solution (150 µL): laboratory water as a control to which all field samples were compared, influent, BUR1, and BUR2. Plates were covered to prevent evaporation and placed in an incubator at 25℃. At 24 h, the water in each well was renewed and any mortalities noted and removed. At 48 h, any mortalities were again noted, and each surviving embryo was manually removed from the chorion if not already hatched. Embryos were then embedded in 3% methylcellulose to immobilize them and digital videos and images were made of each embryo. Digital images were analyzed using ImageJ software (https://imagej.nih.gov/ij/index.html).

Morphometric endpoints assessed were embryo length, eye area, and pericardial area. Stormwater is rarely acutely lethal to zebrafish embryos and rarely impacts embryo length, but eye area typically is smaller in stormwater-exposed embryos (microphthalmia) and pericardial area increased (pericardial edema). Morphometrics were assessed statistically by a linear mixed effects models, similar to the analysis for chemical performance described above. The number of organisms used per event was sufficient to allow a more sensitive significance level of $\alpha = 0.05$. Embryo survival was not impacted in the current study; there was <3% mortality in any treatment for any event.

Results & Discussion

Water Chemistry

The retrofit detention pond generally improved the quality of stormwater runoff; water leaving the pond had lower concentrations than influent runoff for 79% of cases (analytes x events; Table 3). Most of that benefit was provided by BUR1; concentrations were reduced by BUR1 for 85% of cases, whereas BUR2 provided additional concentration reduction in only 56% of cases (Table 3).

Table 3. Frequency of concentration differences across events between influent runoff (INF), water sampled after the first BURito (BUR1) and after the second (BUR2). Cases excluded when influent (INF) sample was below detection limit.

Class	Analyte	INF > BUR1	n	BUR1>BUR2	n	INF>BUR2	n
metal	dCu	75%	4	100%	2	100%	2
	dZn	100%	4	100%	2	100%	2
	DOC	100%	4	100%	2	100%	2
conventional	Ammonia	100%	2	100%	1	100%	1
	Nitrates	75%	4	0%	2	50%	2
	Total P	100%	2	100%	1	100%	1
	TSS	50%	4	0%	2	50%	2
PAH	Pentachlorophenol	100%	4	50%	2	100%	2
	Pyrene	67%	3	0%	1	0%	1
	Benzo(g,h,i)perylene	67%	3	0%	1	0%	1
phthalate	Dimethylphthalate	100%	4	na	0	100%	1
	Di-n-octyl phthalate	100%	3	na	0	100%	2
Summary		85%	41	56%	16	79%	19

Although the small number of samples in the current study limited statistical power, the improvement in water quality at BUR1 was statistically significant across the entire study for dissolved zinc, pentachlorophenol, dimethylphthalate, total phosphorus, and nitrates (Figure 1; $p \leq 0.1$).

Whereas INF and BUR1 were paired to assess treatment of runoff at the first BURito, this water subsequently interacted with the pond itself prior to being treated by BUR2 at the end of the pond. A fair assessment of the benefit provided by BUR2 would have required taking an additional water sample just prior to BUR2. It is possible that water treated by BUR1 picked up contaminants from the pond itself prior to treatment at BUR2, reducing the apparent effectiveness of the BURito treatments for the pond as a whole.

For analytes detected in all four events, results are compared with previous studies of the treatment of roadway runoff chemicals by other green stormwater infrastructure: a compost amended bioswale (CABS) treating runoff on S.R. 518 (SeaTac, WA) and an experimental bioretention installation (BIO) treating runoff from I-5 and surrounding land-uses (Seattle, WA). CABS treating roadway runoff from S.R. 518 (Tian et al. 2019) and the second year of bioretention receiving roadway runoff from I-5 (and surrounding land uses; McIntyre et al. 2020). CABS are designed to provide horizontal flow treatment of runoff primarily through interaction with compost and vegetation. Bioretention is designed to provide treatment by gravity infiltration through a 60:40 mix of sand and compost (by volume). In all three cases, the systems had treated real-time inputs of roadway runoff for at least one wet season (BURitos: 8 months, CABS: 7 years, BIO: 13 months). Performance of the detention pond retrofit with BURitos was intermediate between that of the CABS and BIO for dissolved contaminants including copper, zinc, and organic matter (Table 4). BURitos additionally exported less nitrates than in the bioretention study. In contrast, the BURitos did not appear to perform well for removal of total suspended solids, with performance poorest for BURitos and best for bioretention.

Table 4. Performance as median percent removal from the current study (BURitos), a compost-amended bioswale (CABS), and a bioretention installation. All systems received real-time inputs of roadway runoff for at least 7 months (including one rainy season) prior to sampling of influent and effluent waters. Numbers of rain events included for each system. Ranges are included for percent removal.

	BURitos		CABS[1]	Bioretention[2]	Performance Comparison
	% Removal of Contaminant from Influent Stormwater Runoff				
Analyte	BUR1 (n=4)	BUR2 (n=2)	Effluent (n=6)	Effluent (n=4)	
dCu	45%	54%	23.5% (-150-70%)	62% (56-83%)	BIO>BUR>CABS
dZn	47%	83%	10% (-65-50%)	93% (90-94%)	BIO>BUR>CABS
DOC	41%	51%	na	-3.5% (-150-45%)	BUR>BIO
Nitrates	45%	-82%	na	-143% (-370-29%)	BUR>BIO
TSS	18%	1%	79% (62-92%)	91% (90-93%)	BIO>CABS>BUR

d = dissolved; DOC = dissolved organic carbon; TSS = total suspended solids

[1] Tian, Z., Peter, K., Wu, C., Du, B., Leonard, B., McIntyre, J.K., Kolodziej, E.P. 2019. Performance Evaluation of Compost-Amended Biofiltration Swales for Highway Runoff Treatment in Field and Laboratory. Technical report prepared for WA Department of Transportation and the Federal Highway Administration.

[2] McIntyre, J.K., Davis, J., Knappenberger, T.J. 2020. Plant and Fungi Amendments to Bioretention for Pollutant Reduction over Time. Final Report to Washington State Department of Ecology Stormwater Action Monitoring.

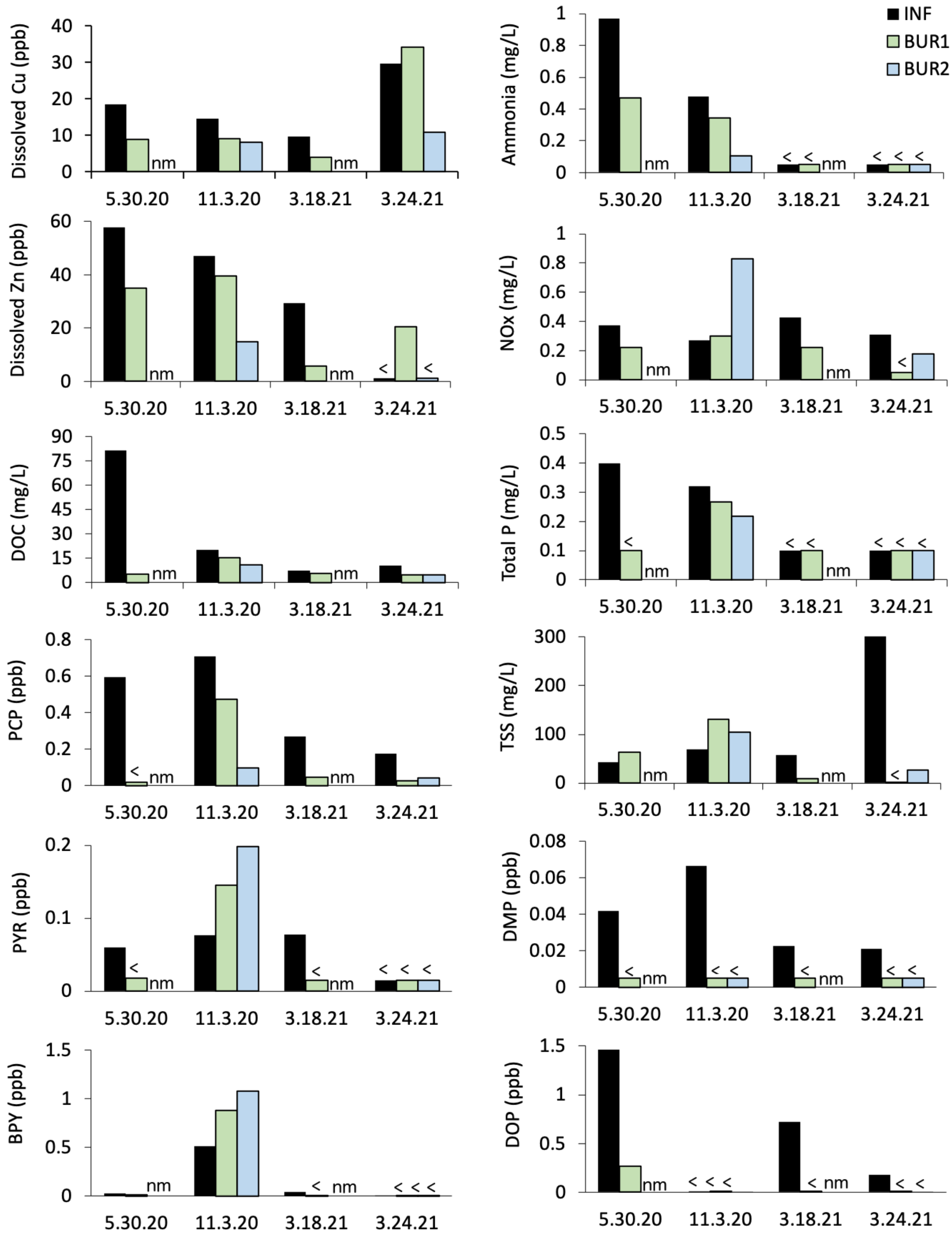

Figure 1. Influent and effluent water chemistry (after the first BURito and after both BURitos) across the study. Samples are unique. DOC = dissolved organic carbon, PCP = pentachlorophenol, PYR = pyrene, BPY = benzo(g,h,i)perylene, NOx = nitrates, TSS = total suspended solids, DMP = dimethylphthalate, DOP = di-n-octyl phthalate, nm = not measured, < = below detection limit.

Toxicology

Zebrafish embryo eye area and pericardial area were significantly impacted by influent runoff ($p < 0.001$). The average impairment across events was an 11% reduction of eye area and a 16% increase in pericardial area (Table 5). Zebrafish embryo growth was not significantly impacted by influent runoff ($p = 0.160$). These results were consistent with previous research with stormwater showing that eye area and pericardial area are sensitive morphometrics but that length is less frequently impacted (McIntyre et al. 2014).

The retrofit detention pond significantly improved the morphometric indicators of acute toxicity (Figure 2). The average improvement across events was 80% for eye area and 89% for pericardial area (Table 5). Most of this benefit was attributable to treatment at BUR1; with a 55% improvement in eye area and a 52% improvement in pericardial area.

This improvement resulted in embryos indistinguishable from controls for pericardial area (103% of control values; $p = 0.513$; Figure 2), whereas the eye area of embryos (93% of controls) was still significantly smaller ($p = 0.024$). This result is identical to experimental treatment by bioretention whereby pericardial area was improved to control levels (103% of control values), and eye area at 93% of control values was still statistically lower than controls (McIntyre et al. 2014). The results of the current study can also be compared with the two systems described above; CABS treating roadway runoff from S.R. 518 (Tian et al. 2019) and the second year of bioretention receiving roadway runoff from I-5 (and surrounding land uses; McIntyre et al. 2020). In those studies, small impairments in eye area and pericardial area were usually but not always improved to the level of controls. Performance of the retrofit pond appeared better than the CABS and similar to if not better than bioretention (Table 5).

Table 5. Effect of roadway runoff on zebrafish embryos relative to clean water controls and improvements provided by BURito treatment. Statistical significance applies only to the BURito data.

	BURito Study (n=4)			CABS (n=5)	Bioretention (n=4)
Metric	INF→BUR1	BUR1→BUR2	INF→BUR2	INF→EFF	INF→EFF
Eye Area	55%	29%	80%*	51%	81%
Pericardial Area	52%	23%	89%^	63%	75%

Effluents: *Significantly different from controls ($p<0.05$) ^ Indistinguishable from controls ($p=0.513$)

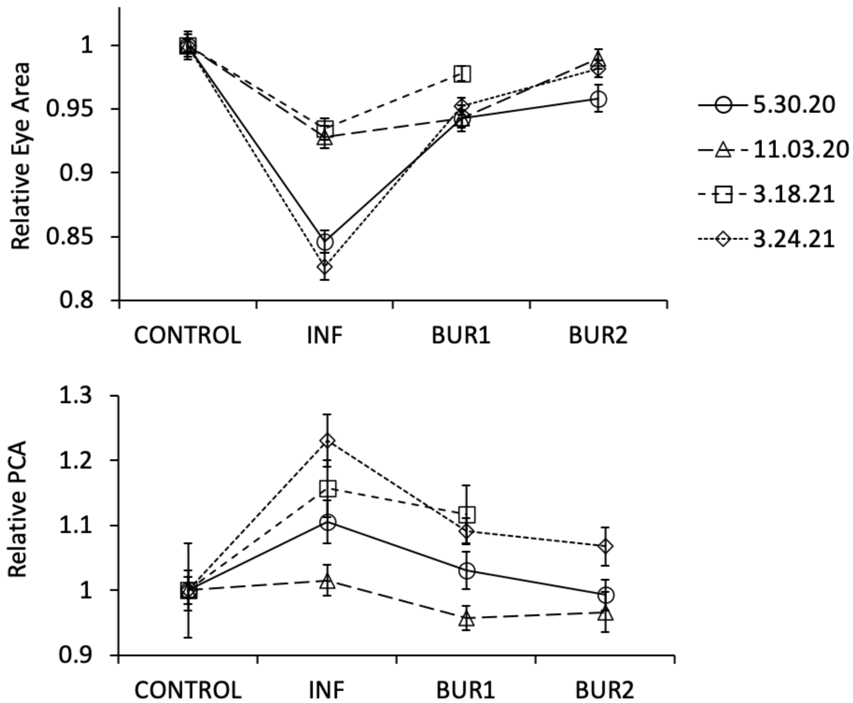

Figure 2. Eye area and pericardial area relative to controls exposed to clean laboratory water for zebrafish embryos exposed for 48 h to influent runoff (INF) or water collected after the first (BUR1) or second (BUR2) BURito in the stormwater detention pond. A linear mixed effects model showed that influent runoff created acute developmental toxicity by decreasing embryo eye area and increasing pericardial area but that BURito treatment significantly reduced the effect on eye area and eliminated the effect on pericardial area.

Conclusions & Implications

Similar to the benefits previously described for bioretention installations, the retrofit stormwater detention pond provided good removal of most targeted pollutants and prevented acute toxicity. The treatment ability of green infrastructure is presumed to be related to contact time between stormwater and treatment media (Hunt et al. 2012). Because runoff was being treated by lateral flow through the coarse BURito media, we expected that BURito performance would be more comparable to bioswale performance than to bioretention treatments that rely on gravity flow through a finer media. However, removal of dissolved metals and organic matter was intermediate to that of bioretention and bioswales. On a contact time basis, this result makes sense because treatment flow through a single BURito was approximately 0.5-4.0 horizontal cm/min, which is similar to that of bioretention (0.5-1.5 vertical cm/min) whereas CABS treated runoff at a much higher rate (approximately 85 horizontal cm/min). Less nitrates leached from the BURitos than from bioretention, which may be related to the use of coarser compost-containing media (lower surface:volume for leaching). Additional study is needed to evaluate the contact time (including surface area) between these treatment approaches to better understand their relative performance. Finally, the BURitos showed a wide range in treatment of TSS, with export in 2020 and high removal in 2021 (~50%

export up to ~100% removal). More testing is needed to assess whether TSS is effectively treated by the BURitos.

Unlike water chemistry performance, reduction of toxicity provided by the BURitos was better than for bioswales and on par or even better than for bioretention. Although we have identified the primary toxicant driving acute mortality in Coho Salmon exposed to roadway runoff (6PPD-quinone; Tian et al. 2021), we have yet to confirm what toxicant(s) drive the sublethal toxicity for less sensitive species, represented here by zebrafish. The toxicology results showed that the bulk of treatment occurred at the first BURito. Among the contaminants measured in this study, pentachlorophenol (PCP) might be most comparable to 6PPD-quinone as it is an aromatic hydrocarbon with similar hydrophobicity (low K_{ow} = 5.1 vs 5.3). PCP was reliably removed by the retrofit pond (median removal ~80%), with the bulk of the removal occurring at the first BURito (Figure 2). Overall, these pilot test results support that one BURito was better than none (BUR1 vs influent water chemistry and toxicity), and that two BURitos generally provided better treatment than just one.

One shortcoming of the study was not sampling water immediately prior to BUR2. As described above, the pairing in proximity and time of influent and BUR1 samples allowed us to confidently assess the performance of BUR1, however water treated by BUR1 travelled the length of the pond before encountering BUR2 and leaving the pond. A sample of water immediately prior to BUR2 treatment would have prevented the uncertainty around whether the pond itself contributed to treatment and/or pollution of runoff. A better assessment would be sampling influent and effluent waters from an existing detention pond before and after BURito installation across comparable time periods (e.g. 6-12 months).

We believe that retrofitting existing detention ponds with BURitos should be evaluated as a future best management practice. Some key design parameters that need to be defined are:

- Flow rate accommodated by a BURito as a function of BURito diameter
- Treatment level as a function of flow rate
- Total volume treated by a BURito (life span)
- Inspection/maintenance requirements
- Rate of sediment build up upstream of a BURito and its effect on treatment level
- Volume of runoff treated vs overtopping BURitos for storms of different sizes
- Sizing of BURitos: how many are needed to effectively treat a pond based on maximum flow rates, contributing area, and treatment area?

The cost of pond retrofit was approximately $15,000 including inlet modification, biofiltration berm construction, and labor costs. Given the relatively low operations and maintenance cost of the BURitos, this pond retrofit is a cost-effective water quality treatment compared to installing new water quality retrofit stormwater facilities in the right-of-way. We believe it is feasible to annually incorporate the retrofit of one or more ponds into existing programs through routine work and budgets given the existing requirement under NPDES Municipal Permits to inspect and maintain existing stormwater detention ponds.

The City of Bellevue is located within the Wastewater Treatment Division (WTD) service area of King County. The successful water quality treatment retrofit demonstrated by this project can be replicated throughout the WTD service area. By treating urban runoff such that aquatic organism impairment is reduced within the City of Bellevue, and the potential for other areas to conduct these improvements, rate payers will benefit from direct environmental enhancement.

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Appendix 1

Specifications for the coarse sand (unwashed utility sand) used in the BURitos.

Aggregate Sieve Size	% Passing
3/8”	100
#4	94-100
#8	40-60
#16	20-30
#40	4-10
#100	0-4
#200	0-2

Appendix 2

Specifications for medium compost used in the BURitos.

1. Compost material shall be tested in accordance with Testing Methods for the Examination of Compost and Composting (TMECC) Test Method 02.02-B, “Sample Sieving for Aggregate Size Classification”.

Medium Compost shall meet the following:

% Passing	Min	Max
2”	100%	
1”	100%	
5/8”	85%	100%
1/4"	70%	85%

2. Maximum particle length shall 4 inches be for Medium Compost.

3. pH shall be between 6.0 - 8.5 determined by TMECC 04.11-A, “1:5 Slurry pH”.

4. Physical contaminants, defined in WAC 173-330 (plastic, concrete, ceramics, metal, etc.) shall be less than 0.5 percent by weight as determined by TMECC 03.08-A “Classification of Inerts by Sieve Sizes”.

5. Minimum organic matter shall be 40 percent dry weight basis as determined by TMECC 05.07A, “Loss-OnIgnition Organic Matter Method (LOI)”.

6. Soluble salt contents shall be less than 4.0 mmhos/cm tested in accordance with TMECC 04.10-A, “Electrical Conductivity”.

7. Maturity shall be greater than 80% in accordance with TMECC 05.05A, “Germination and Root Elongation”.

8. Stability shall be 7-mg CO2–C/g OM/day or below in accordance with U.S. Composting Council TMECC 05.08-B “Carbon Dioxide Evolution Rate”.

9. The compost product must originate from feedstocks as defined in WAC 173-350 as “Wood waste”, “Yard debris”, “Post-consumer food waste”, and/or “Preconsumer vegetative waste”.

10. Feedstocks shall originate from local recycling collection programs and contain a minimum of 10% post-consumer food waste as defined in WAC 173-550.

11. The Engineer may also evaluate compost for maturity using U.S. Composting Council TMECC 05.08-E “Solvita® Maturity Index”. Medium compost shall score a 5 or above on the Solvita® Compost Maturity Test.