PORT OF SEATTLE

INNOVATIVE STORMWATER OPERATIONS AND TREATMENT TECHNIQUES

Category: Environmental Enhancement

Sandra Kilroy
Director Maritime Environment & Sustainability, Director Marine Stormwater Utility
Port of Seattle
2711 Alaskan Way Seattle, WA 98121

Date submitted: June 13, 2019

Introduction

The Port of Seattle (Port) established environmental protection as a Century Agenda goal of the organization. The environmental and technical framework for meeting this goal in the Puget Sound region includes some of the most stringent water quality standards in the U.S. and the critical state of Southern Resident Killer Whales, a priority of Washington State's Governor.

The Port has approximately 1,000 acres of maritime property draining into the Puget Sound, Elliott Bay and Duwamish Waterway, and plays a significant leadership role in modeling stormwater management best practices for maritime industries. In 2014, the Port created the Marine Stormwater Utility (Utility) to direct resources to the challenges of meeting stringent stormwater permits and maintaining and upgrading the Port's stormwater infrastructure.

Goals and Strategies

The Port's Century Agenda goals include being the greenest port in North America, with a strategy to meet or exceed agency requirements for stormwater leaving Port-owned or operated facilities. This agenda helps drive innovations and improvements to technologies that benefit water quality. The three innovations discussed below were developed to address operational needs where equivalent commercial products were not readily available or were prohibitively expensive. Each innovation ultimately aids in the reduction of pollutants entering stormwater, resulting in improved water quality and a healthier environment to benefit the Puget Sound.

Discussion

Dock Scrubber

Marine docks accumulate contaminants from routine operations of loading and unloading equipment and cargo and from birds congregating on or above the docks. Most pressure washer/scrubbers used to clean docks do not recover much if any wash water, allowing it to drain into a stormwater system or directly into an adjacent water body.

To solve the problem of cleaning docks without discharging wash water, the Port's Marine Maintenance staff developed a dock scrubber that recovers virtually all wash water (Figure 1). The unit addressed a gap between operations and regulations: existing City of Seattle code at the time (2009) allowed for wash water to drain into the stormwater system if it did not contain oils or detergents; the Washington State Department of Ecology did not allow wash water discharge even without additives and considered the routine maintenance of dock cleaning as a polluting activity.

With no commercial system available to address the Port's need to keep docks clean, safety and pollution build-up became problems. Criteria for a system included operations that extend to docks up to 1,000 feet from upland support areas, effective scrubbing and suction to clean and capture debris, and efficient water and energy use.

Maintenance staff were incredibly innovative and persistent. Initial attempts to create a system included a pressure washer unit with a port to allow for used wash water to be collected but with no collection system; a wet/dry vacuum that filled in minutes, far too quickly to efficiently clean the full length of a dock; and a collection hose from a vacuum truck that needed to be modified to collect the wash water and protect the truck from damage, and to fit a small scrubber.

Figure 1 - Dock Scrubber Unit

To successfully retrofit the truck and create a working dock scrubber, the suction power was modified via a custom-built system:

- a reducer fitting to decrease the 8" hose diameter to 4",
- a 4" ball valve to control air flow with a screen to prevent injury, and
- a camlock 2" reducer for easy connection and to further reduce the hose diameter to accommodate the size of the scrubber outlet.

The initial test succeeded, so the Port made an additional investment to purchase 1,000 ft. of 2" hose reel to extend the system the full extent of the docks (Figure 1, see 2" yellow hose). The dock scrubber unit has been a success and is used to annually clean a portion of the docks owned and operated by the Port, as well as plazas, sidewalks, pedestrian bridges, and roofs.

Because of our success with the dock scrubber at Port-owned properties, the Washington State Department of Ecology included the dock scrubbing system in its *Stormwater Management Manual for Western Washington 2019* draft (see Volume IV "Source Control BMP Library," section IV-2 "Cleaning or Washing Source Control BMPs," subsection S434 "BMPs for Dock Washing"). A video on the Port's YouTube channel (link: https://www.youtube.com/watch?v=7RBFdjC3K1Q) shows the unit in operation, and a link to the video is posted on Ecology's website (link: https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Municipal-stormwater-permit-guidance#subsections) in the "Operation and Maintenance" section. Recently a commercially available system for dock scrubbing

and pervious pavement cleaning has become available that is similar to the system designed by Port staff.

Oyster Shell Barrels

As part of past Port water quality initiatives, oyster shells were used as treatment media at Port industrial facilities. These oyster shells are placed directly in catch basins, and monitoring data shows significant reductions in zinc, copper, and turbidity, enabling the facility to meet strict water quality benchmarks.

More recently, the Port decided to apply this method to roof runoff, a source of potential pollution, especially those facilities close to elevated highways. A commercial property, the Port's Terminal 102, was selected and 30-gallon plastic barrels containing oyster shells were installed on roof downspouts to treat runoff prior to discharge into the stormwater system. A total of 22 barrels were placed against the office building to minimize impact on commercial parking. This location is adjacent to the West Seattle Bridge, a major thoroughfare across the City of Seattle that contributes to aerial deposition of roadway pollution onto area roofs.

Each barrel has an inlet pipe plumbed to a roof downspout that extends to the bottom of the barrel. The outlet pipe extends from the bottom to about two-thirds up to the top and is connected directly to the stormwater system. The stormwater from the roof seeps through the oyster shells to the bottom of the barrel, and then flows up the outlet pipe and into the stormwater system.

Effectiveness of the oyster shell system in reducing contaminants was monitored at two locations approximately every four months since late 2016, when the barrels were installed. The monitoring measured copper, zinc, and turbidity, and detailed results, including sample locations, are provided in Appendix A. The average results for percent reduction at are shown in Table 1.

Table 1 - Oyster Shell Monitoring Percent Reduction Data Averages

Location	Turbidity	Zinc	Copper
Point A	55.24%	39.55%	29.27%
Point B	59.83%	42.43%	24.60%
Total Averages	57.53%	40.99%	26.94%

The results show that significant reductions in metals and turbidity are achieved by the oyster shell barrels. Over time, the oyster shells lose effectiveness, and there is a risk that metals can be released into stormwater from the shells. We have learned from the catch basin and roof down spout monitoring that at approximately 12 to 14 months the used shells need to be replaced with new or refreshed shells. Our standard operations involve changing oyster shells every 12 months.

To help describe the system for a general audience, a mockup of the oyster shell barrel was created and has been used to educate at trainings, conferences and other public events (see Appendix A, Figure A-3). It is the actual size of the unit, cut in half, holding Styrofoam peanuts in place of oyster

shells to decrease weight and not waste oysters, and clearly shows the plumbing and other unique features of the barrels.

Media Washing Machine

When the Port first began using oyster shells for stormwater treatment, the shells came clean and ready to be installed in catch basins or barrels. When used shells needed to be refreshed, the cleaning was done by hand, which was time consuming and costly. With the increased use of oyster shells for stormwater treatment and difficulty acquiring clean shells, the need for cleaning newly acquired shells or refreshing used shells has become more critical. It has also become more economical to use existing shells by refreshing rather than replacing with new ones that need washing. To address this need, a media washing machine was devised by Marine Maintenance staff (Figure 2). The unit is loaded via a backhoe or by hand via a ladder, and materials placed into a bucket. The machine has capacity for ½ cubic yard of material.

Figure 2 - Media Washing Machine

A motor attached to the side rotates the cage, which sits on rollers, while water is sprayed on the media through a fixed pipe down the entire length of the unit (see Appendix B). In approximately 30 seconds, the shells come out cleaned and ready to be used in stormwater treatment applications. Other course media, such as rock or gravel, can also be efficiently cleaned using this system.

This washing unit streamlines and significantly increases efficiency of refreshing oyster shell media, allowing it to return to use relatively quickly. The cost of the machine, including labor and troubleshooting problems, was under $20k. The unit needs to be connected to a water source, which is readily available in the Marine Maintenance yard where the oyster shells are stored, and discharge goes to sewer. The unit can also be loaded onto a trailer and taken to a facility to refresh oyster shells on site, but a water source and appropriate discharge option, such as to sewer or Baker Tank, is necessary. We expect that oyster shells can be refreshed many times before they are no longer effective as treatment but have not yet determined the refresh frequency for our various applications.

Fulfillment of Awards Criteria

Washington has some of the most stringent water quality regulations in the U.S. To meet environmental challenges and ensure stormwater discharge meets requirements, Port staff have been innovative and experimented with environmental enhancement technologies with great success.

Benefits to Environment and Community

The Port has shown that oyster shells effectively remove contaminants and improve water quality, documented in data tables in this application and Appendix A. The simplicity and low cost of oyster shells allow for use in a wide variety of applications. At the Port, they are used at some facilities where no treatment is required, supporting our goal to exceed regulatory compliance. The media washing machine supports refreshing oyster media for reuse a number of times before disposal.

The dock scrubber helps keep public docks clean and safe for moorage and live-a-board customers while reducing pollution by recovering all wash water therefore benefitting the water quality of Puget Sound.

Independent Involvement and Effort

Port staff independently developed the dock scrubber and media washing machine to address needs where no commercial products were readily available.

The Port has been a regional leader in using oyster shells for stormwater treatment. There was limited information on the viability of using oyster shells as stormwater treatment media before the Port began its various applications and monitoring efforts. The Port organization has consistently been supportive of these various efforts.

Creativity of the Program

The dock scrubber cleans docks at routine intervals or when needed, minimizing impacts to the surrounding waters. The oyster shell barrels and media washing machine support low profile or small footprint stormwater treatment systems at reduced capital and maintenance costs.

For all these innovations, Port staff were creative and openminded, and as a result, developed solutions to stormwater and water quality operations challenges. Port staff took it upon themselves to develop a new product where none were commercially available. This has kept costs down and made use of the creative problem-solving talents of Port maintenance staff.

Project Results

The innovations outlined in this application have been incredibly successful. Oyster shells have been shown through monitoring data to reduce certain contaminants, and dock scrubbing is used regularly by the Port to minimize discharges from dock cleaning. The average contaminant reductions from oyster shell barrels have been very good for copper (high of 100% reduction), zinc (high of 97% reduction) and turbidity (high of 89% reduction; see Appendix A). The dock scrubber is currently used to clean all the Port docks on a regular schedule. The media washing machine supports the efficient cleaning or media and keeps oyster shells in use longer.

Cost Effectiveness of the Program

The Port used internal staff and maintenance facilities to design and build the dock scrubber, oyster shell barrels and media washing machine. The oyster shells used in the barrels were acquired from local businesses in the seafood industry at minimal cost.

The cost per square foot treated by oyster shell barrels is significantly less than most other commercial treatment systems used on Port properties. Ongoing maintenance involves annual replacement or refreshing of shells to ensure optimal performance, and the media washing machine ensures a ready supply of clean or refreshed shells.

Although the dock scrubber requires an operator for the vacuum truck at all times during the activity, which adds labor costs, this cost is known and can therefore be included in the annual budget.

Transferability to the Port Industry

These relatively simple innovations are readily adaptable to other Ports. We share our designs, technical details, and effectiveness data with any entity who requests information.

Conclusion

The initial results using oyster shells as stormwater treatment media have been positive, the media washing machine prolongs the use of the shells to minimize costs, and the dock scrubber has demonstrated a system for keeping docks safe and clean while eliminating discharges to receiving waters. These innovative ideas help the Port achieve our goal to be the greenest port in North America, and to meet or exceed agency requirements for stormwater leaving Port-owned or operated facilities.

Appendix A – Oyster Shell Barrels

Figure A-1 – Terminal 102 site layout and sample points

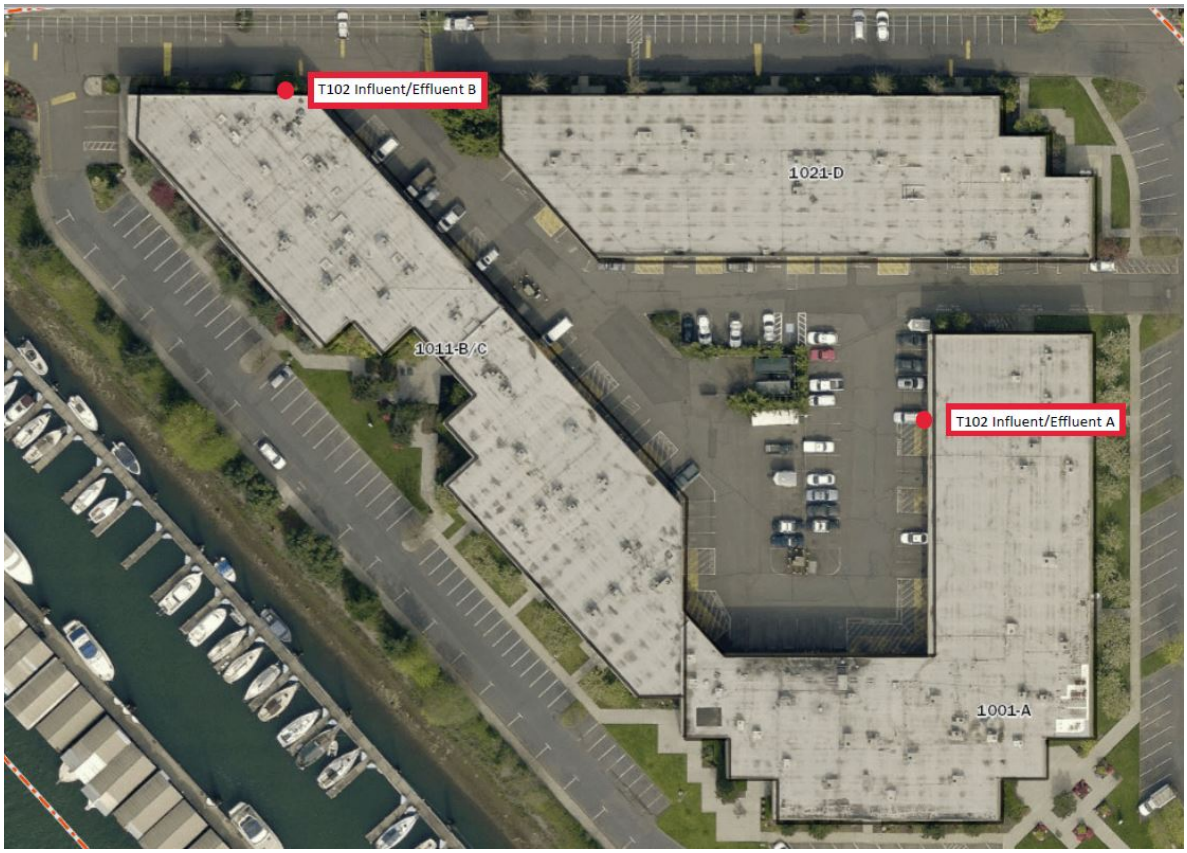

Figure A-2 - Barrels installed onsite

Figure A-3 – Mock-up barrel for education

Notes for Tables A-1 and A-2: Monitoring results were collected for influent and effluent at two oyster shell barrels (points A and B, see Figure A-1). Measurements are compared against industrial stormwater benchmarks, as follows:

- pH range: between 5.0 and 9.0, standard units
- Turbidity: 25 NTU
- Zinc: 117 µg/L
- Copper: 14 µg/L

Reductions in turbidity, zinc and copper are tracked, and pH is monitored to ensure it stays in the 5-9 range. More acidic pH (<5.0) indicates that metals may begin releasing into solution. The dark blue cells indicate very positive results, while red cells indicate increases in contaminants between influent and effluent.

To determine when oyster shells would begin to release metals back into stormwater, we delayed changing oyster shells from 10/18/2017. Breakthrough was noted in samples taken on 3/7/2019, 17.5 months later. This confirmed that our standard operations of changing oyster shells every 12 months was a protective assumption.

Table A-1 – Oyster Shell Monitoring Data at Sample Point A

Sample Date	Sample point A	pH	Turbidity	Zinc	Copper
3/10/2017*	Influent	9.42	5.00	51.0	0
	Effluent	8.16	2.01	35.0	0
	% reduction		59.80%	31.37%	0.00%
10/18/2017*	Influent	7.15	26.40	120.0	22.0
	Effluent	7.61	2.85	3.9	0
	% reduction		89.20%	96.75%	100.00%
1/11/2018	Influent	7.89	1.32	36.0	6.9
	Effluent	7.62	1.05	28.0	4.6
	% reduction		20.45%	22.22%	33.33%
4/4/2018	Influent	6.95	6.90	34.0	6.3
	Effluent	7.08	1.91	14.0	4.6
	% reduction		72.32%	58.82%	26.98%
10/5/2018	Influent	7.72	14.60	32.0	4.7
	Effluent	7.12	5.34	23.0	4.6
	% reduction		63.42%	28.13%	2.13%
3/7/2019*	Influent	9.05	8.61	18.0	5.6
	Effluent	7.95	6.35	18.0	6.5
	% reduction		26.25%	0.00%	-16.07%

Note: * indicates approximate date of oyster shell replacement.

Table A-2 - Oyster Shell Monitoring Data at Sample Point B

Sample Date	Sample point B	pH	Turbidity	Zinc	Copper
3/10/2017*	Influent	8.14	4.23	85.0	0
	Effluent	6.68	2.21	74.0	0
	% reduction		47.75%	12.94%	0.00%
10/18/2017*	Influent	7.73	29.80	350.0	49.0
	Effluent	7.70	4.85	20.0	6.8
	% reduction		83.72%	94.29%	86.12%
1/11/2018	Influent	7.95	1.61	50.0	5.5
	Effluent	7.49	0.54	39.0	5.0
	% reduction		66.46%	22.00%	9.09%
4/4/2018	Influent	7.10	5.54	64.0	7.4
	Effluent	7.00	1.26	24.0	4.9
	% reduction		77.26%	62.50%	33.78%
10/5/2018	Influent	7.33	15.30	52.0	5.7
	Effluent	7.14	3.05	31.0	5.0
	% reduction		80.07%	40.38%	12.28%
3/7/2019*	Influent	7.80	5.67	49.0	8.2
	Effluent	7.58	5.46	38.0	9.7
	% reduction		3.70%	22.45%	-18.29%

Note: * indicates approximate date of oyster shell replacement.

Appendix B – Media Washing Machine

Figure B-1 - Fixed Water Pipe

Figure B-2 - Water Inlet Connection

Figure B-3 - Oyster Shells

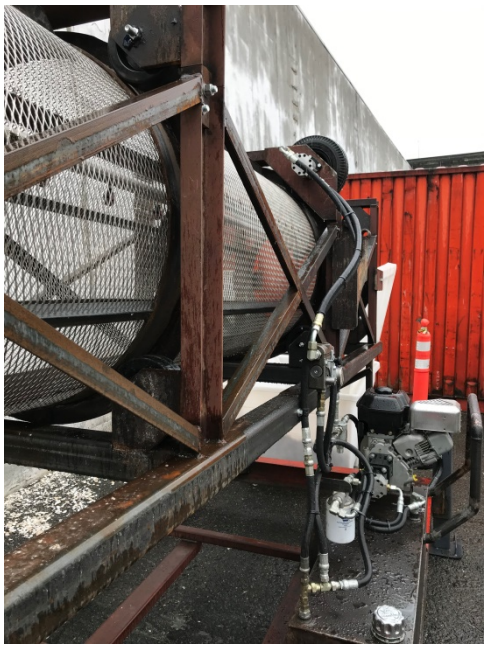

Figure B-4 - Motor Attachment