Emerging Best Management Practices in Stormwater: Street & Surface Sweeping to Reduce Stormwater Pollution



Introduction

S tormwater is the leading contributor to water quality pollution in Washington State.¹ For this reason, the Washington Department of Ecology requires businesses and municipalities to control stormwater pollutants, such as heavy metals and organics. Strict limits on zinc require a number of Washington organizations to use source control or treatment measures to reduce zinc in runoff. According to Lisa Rozmyn, the Washington Stormwater Center's Business Resource Manager, "Zinc is difficult to control because it's everywhere in industrial sites and equipment."

With support from the Russell Family Foundation, the Pacific Northwest Pollution Prevention Resource Center (PPRC) is helping businesses navigate a tangle of emerging zinc-reduction technologies and techniques to achieve acceptable stormwater quality. As an unbiased non-profit resource, PPRC seeks to promote stormwater practices that are economically and environmentally beneficial.

This report focuses on the efficacy of sweeping practices to reduce stormwater pollution. It is one in a series that explores emerging techniques and practices to manage zinc in stormwater. Other report topics include: *Biochar as Filtration Media, Mitigating Zinc in Boatyards,* and *Addressing Galvanized Roofing.*



Brushing Up on Sweeping

When dealing with stormwater pollution problems, sweeping should factor early in your management plan. In fact, "vacuum sweeping" of paved surfaces is a required element of "good housekeeping" practices for all Washington Industrial Stormwater General Permit holders.² While sweeping is a simple idea, things get complicated fast when you're faced with preparing a specific plan and budget. After all, what is "vacuum sweeping"? How about "regenerative sweeping"? Do you do things differently in the "wet" versus the "dry" season? And how often should you sweep?

Identifying Zinc Sources

The first step in stormwater compliance is to identify and understand your pollutant sources. Zinc is found on most industrial sites from three major sources:

- Galvanized metal surfaces Zinc is used to fight corrosion, but does so by dissolving into water.
- Motor oil and other vehicle fluids Zinc is used for corrosion control in lubricants, hydraulic fluid and other engine additives.
- Tire dust Zinc is used in the production of tire rubber and makes up about one percent of tire dust.

Keep an eye out for these major sources, but remember that zinc-containing dust may also land on your property from roadways or nearby industrial activity. An in-depth discussion of zinc sources can be found in the Washington State Department of Ecology's "Suggested Practices to Reduce Zinc Concentrations in Industrial Stormwater Discharges."³ The guide includes an excellent Zinc Source Inventory Worksheet.

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Will Sweeping Work for You?

Test results for zinc in stormwater usually indicate both "total recoverable" (TR or total) and "dissolved" zinc. Roughly speaking, the difference between these two values reveals the amount of zinc associated with solid particles (total zinc – dissolved zinc = particle zinc). Sweeping can be effective at reducing both types of sources since dissolved zinc is often attached to particles during some part of its lifetime. Sweeping can also be beneficial in reducing other stormwater pollutants, such as:

- Other heavy metals for example, copper, lead and cadmium from vehicle wear particles, brake pad breakdown, building flashing, or other materials.⁴
- Total Suspended Solids (TSS) Industrial activities often generate lots of debris that eventually breaks down to small particles. These particles along with heavy equipment and vehicle wear dust can be major sources of TSS.
- Petroleum Hydrocarbons Many chemicals are not soluble in water and prefer to latch on to particle debris; capturing particles before they reach stormwater can reduce Total Petroleum Hydrocarbons (TPH) and other vehicle chemical additives that are harmful to aquatic life.

Professional sweeping services won't always be the best solution. Discuss your site sampling and test results with a knowledgeable advisor or stormwater professional. For example, sweeping may not solve your problem if zinc exceedances are caused by dissolved zinc from galvanized roofing. In isolated locations, metal shavings may be removed efficiently and cheaply by an industrial vacuum cleaner or ordinary push-behind sweeper. Occasional pressure washing with water reclamation

may be more cost-effective than routine sweeping for some situations. On the other hand, high vehicle traffic, truck loading



and unloading zones or fork lift activity are all notorious for high zinc from tire wear, which should respond well to sweeping.

As always, it's important to use good housekeeping practices to keep particle pollution away from stormwater runoff. If you process metals or other polluting materials as part of your business, keeping these materials away from water is most likely the least expensive approach. Finally, remember to consider legacy sources that can lie in the often hidden piping network that conveys stormwater from source to outfall. To fully realize sweeping benefits, you may need to clean, repair, or replace catch basins, stormwater lines, and galvanized piping materials.



Figure 2: Typical debris at a loading dock. High truck traffic and sharp turns can generate significant tire wear particle pollution, a major source of zinc.³



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Sweeper Types

Historically, street sweeping was primarily an esthetic issue: dealing with the regular buildup of litter and trash along urban streets. Mechanical broom technology has been around for a century and performs beautifully with newspaper, crushed drinking cups, or cigarette butts – visible debris that brings a call from the plant manager or a concerned citizen. **Mechanical sweepers** also do a great job with some tough problems, like wet leaves, which can be significant contributors to nutrient pollution from nitrogen or phosphorus. Industrial facilities can often stay on top of these kinds of debris with small-scale push-behind mechanical sweepers.

Sweeping is also an essential element of managing the less visible pollutants that cause exceedances in suspended solids (TSS), copper and zinc levels. Even after a good mechanical sweep, a significant load of fine particle debris is usually left behind with particles stuck in cracks and crevices or simply too small to reach the sweeper's conveyor belt. These small particles are especially problematic for stormwater pollution. Pound for pound, small particles have a lot more surface area than big particles (see Figure 5).

"Soluble" metals and organic pollutants often prefer a solid surface due to chemical interactions. As a result, smaller particles may carry the bulk of some pollutant types (see Figure 6). Lastly, small particles are more easily suspended and carried away in runoff, leading to turbidity (measured in total suspended solids, or TSS).



Figure 5: Ten pounds of marbles has much more surface area than a ten-pound bowling ball. In other words, poundfor-pound, small particles can carry a lot more surface contamination than large particles. ("Marble" courtesy Gillian @ Flickr / CC: http://ow.ly/Ag01s; "Floating Bowling Ball courtesy NOAA's National Ocean Service @Flickr/ CC: http://ow.ly/AfZLs)

To deal with the small particles, **regenerative sweepers** direct high pressure air nozzles at the surface just ahead of a vacuum pickup system. The air blast kicks up dirt and debris stuck on the surface or hidden in surface cracks. Vacuum sweepers rely on a strong vacuum to lift particles off the surface. Both regenerative and vacuum sweepers employ brushes to clean gutters or to

sweep material into the pickup zone.⁶ Capturing small particles is critical to reducing turbidity. Particles larger than about 250-500 µm tend to settle out in the stormwater system before they reach the effluent, especially with the very low flows caused by the mild, but persistent, rainfall typical of the Northwest.

Rotating brushes or air blasts can kick up a substantial amount of airborne dust that escapes into the surroundings ("fugitive" dust). Sweepers usually combat this with some combination of external (before pickup) or internal (after pickup) water sprays. In most equipment, these sprays can be turned on (wet sweeping) or



Figure 6: Zinc content versus street dirt particle size. "Fine sand" and the other right-most columns represent particles smaller than 250 μ m [5].

Beware of Fine Dirt

Street dirt can also cause significant air pollution. Airborne particles under 10 µm, or PM10 pollution, can reach the deep lung and cause health issues. California's South Coast Air Quality Management District (SCAQMD) certifies sweepers for use in controlling PM10 pollution. These PM10-efficient sweepers employ the same particle capture features as any high-efficiency sweeper. See the Resources section for SCAQMD certified sweepers.

off (dry sweeping). Since fine particles can create havoc with sweeper hardware, leading to internal wear or plugged filters, water sprays are usually turned on by default to protect the equipment.

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Sweeper effectiveness is reduced by the losses of fugitive dust and particles re-emitted in exhaust (vacuum sweepers) or recirculated air (regenerative sweepers). "High-efficiency (HE) sweepers" use internal filters or particle separators to clean the airstream before it gets to the exhaust or recycle. Carefully designed airflow in the capture zone and use of broom skirts enhance particle capture. Removing these fine particles improves sweeping efficiency but burdens businesses with higher capital costs and maintenance requirements. All types of sweepers can utilize "high-efficiency" design features and modern high-efficiency sweepers, either vacuum or regenerative, perform much better than simple mechanical sweepers in most situations. 6,7



Figure 5: Sweeper effectiveness versus particle size, based on research by the United States Geological Survey.⁷ Vacuum assist and regenerative sweepers do a better job recovering the particles associated with suspended solids than do mechanical sweepers.

Does Sweeping Improve Water Quality?

Controlled simulations of sweeping in test environments show remarkable results when using modern sweeping equipment, with regenerative and vacuum sweepers typically capturing 90-plus percent of simulated street debris in most or all size ranges [3]. So, does sweeping benefit water quality in real urban environments? Quantifying benefits has been a challenge due to:

- The highly variable nature of stormwater loadings and washon/washoff events.
- The difficulty of representative stormwater sampling and testing, especially for particles.

- The use of outdated sweeping equipment (many early studies used less-effective mechanical brooms).
- The large variations in "new" sweeper technology between studies; and
- Uncontrolled variables of urban experiments, e.g., pollutant sources, adjacent land use, street surface quality and atmospheric deposition.

The extreme variability of stormwater requires very large sample numbers to show significant effects, often making the work prohibitively expensive; as a result, studies often show little discernable effect.⁷

However, the most recent studies using modern equipment provide some solid support for sweeping:

- 2005 Vacuum sweepers perform much better than mechanical sweepers⁵: Street-sweeper efficiencies (mass of swept dirt divided by mass of applied dirt) were much better for a vacuum sweeper (60 to 92 percent) than for a mechanical sweeper (20 to 31 percent), though results were for *simulated* street dirt applied by a spreader.
- 2007 Regenerative sweepers and vacuum sweepers were both better than mechanical sweepers, but yields with real street dirt were lower than for studies with simulated dirt⁷: The regenerative-air and vacuum-assist sweepers had similar pickup efficiencies (mass of dirt picked up versus total amount of street dirt) of 25 and 30 percent, respectively. The mechanical broom sweeper was considerably less efficient, removing an average of five percent of street-dirt yield.
- 2009 Sweeping reduces the sediment load to receiving waters, especially in industrial areas⁹: Sweeping streets every other week increased the total amount of sediment removed from the test area compared to the amount removed by catch basin cleaning alone, and will reduce the sediment loading to receiving waters.
 Sweeping streets every other week is also effective when compared to annual catch basin cleaning, increasing the annual sediment removed by ten times that of annual catch basin cleaning alone in a light industrial area (350 g/m²/year versus 34 g/m²/ year).

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 2009 - Sweeping is cost-effective compared even with simple catch basin cleaning⁹: Estimated life-cycle costs for a full-scale street sweeping program (\$0.34 per wet kilogram of material removed) are generally lower than the costs for the SPU city-wide catch basin cleaning program (\$0.42 per wet kilogram). On a life-cycle cost basis, the cost of street sweeping (\$5/kg TSS removed) is about 15 to 50 percent of the cost for an equivalent regional-scale structural BMP (\$10 to \$30/ kg TSS removed) and may be in the five to 10 percent range when compared to small scale, local transportation projects.

The 2009 study results above, by Seattle Public Utilities, used a regenerative sweeper. In spite of these positive results, there are still some significant uncertainties regarding sweeping for stormwater improvement:

- Sweepers still do best with relatively larger particles versus smaller particles – The success of a sweeping strategy will depend on how well larger particle pickup reduces the overall pollutant burden at a given site.
- Sweeping research nearly always addresses curbed streets – Since sweepers are designed to pick up dirt concentrated near the curb, there is little or no research to show quantitative results for sweeping non-curbed streets or lots.
- Sweeping research nearly always addresses dry streets – No research studies were identified that demonstrate pollutant removal for rain-wet streets common to the Northwest.

Some studies⁸ and manufacturer websites¹⁰ report better performance when sweepers are run in dry mode (no water spray) – This significant operating variable is rarely mentioned in the sweeping research. While some manufacturers offer "dry sweeper" designs, there is little research comparing their performance to other sweeper types.

 Modern sweepers can be sensitive to surface quality and road grade or shape¹¹ – Recent research by San Diego's Transportation and Storm Water Department suggests that mechanical brooms can perform better than regenerative and vacuum sweepers on steep road surfaces. Highly degraded road surfaces can also reduce the benefit of advanced technologies.



Working with Sweeping Contractors

For most industrial permit holders, sweeping services will be purchased from an outside provider. Again, before seeking out a contractor, do your best to get a handle on the technical nature of your stormwater problem. Sweeping works best with pavement in good condition. So, when possible, seal surface cracks and crevices and repair deteriorating roads or lot surfaces.

Choosing the Right Contractor

- Check for recommended vendors from trusted sources – Local and state government offices or stormwater centers of expertise may have "approved" sweeping contractor lists. A good contractor will perform a site assessment and be able to tell you how and why sweeping is appropriate for your situation.
- Be sure that sweeping contractors have modern regenerative or vacuum sweeping equipment – These nearly always perform better than mechanical brooms. Highefficiency sweepers are likely to provide better performance than older generation

equipment.

• Discuss the appropriate sweeping frequency for your facility – The site assessment should involve a consideration of sweeping frequency. The minimum quarterly requirement may not achieve the results you need. Also,

remember that sweeping is likely cheaper than any treatment approach, so it may be worth over-sweeping rather than introducing new treatment technology, especially if you are close to achieving your improvement goals.

• Consider a contractor with comprehensive services – It may be more cost-effective to hire a sweeping contractor with a full suite of stormwater services, such as linejetting (required for some locations with impaired receiving waters), catch basin filter maintenance and cleaning, and even stormwater sampling and testing.

Monitoring Contractor Sweeping Practices

- Sweep where the dirt is, but remember to focus on obstacles that trap dirt – As with city streets, curbs and other obstacles can trap particle pollution, but these areas aren't always accessible to large sweeping machines. Contractors can use blowers to air-sweep particle pollution into a machine sweeping zone. Don't blow debris into landscaped areas; this is at best a temporary solution.
- Have sweeping done on dry days Sweepers perform better on dry surfaces. Water mixes with fine particles to create a slurry that can paint the road surface and remain behind after sweeping. Wet sweeping may be your only option, but there is little data on the effectiveness of sweeping under wet conditions.
- **General performance issues** Make sure service providers are not cutting corners by going too fast (sweepers usually operate better at slower speeds), not covering the entire surface, etc. As with any contractor, you should validate the company's credentials and ethics, and ask for reference customers.
- Use the right technology for porous pavement surfaces – Porous surfaces are increasingly required by low-impact development (LID) provisions of building codes. If your site has significant porous surface coverage, be sure to talk with your sweeping contractor about best practices for maintaining surface performance. Industry publications are beginning to address this issue.^{12,13}

Conclusion

Recent research shows that street sweeping can reduce the particle load in stormwater runoff. All particles can cause pollution, but fine particles can carry more than their share of stormwater pollutants. For zinc, other metals, hydrocarbons, but even nutrient pollutants and bacteria, sweeping is likely the most cost-effective measure available to reduce stormwater pollution and requires no investment in real estate or capital construction. The current generation of vacuum or regenerative sweepers are a significant advance over early mechanical broom technology for removing fine particle surface material. When contracting for sweeping services, select vendors with equipment and experience using advanced sweeping technologies, preferably those with "high-efficiency" designs.

Resources

- Washington Stormwater Center's Provider Directory for Sweeping Services.
- Washington State Department of Ecology's Stormwater Management Manual for Western Washington, Volume 4, Source Control BMPs .
- California South Coast Air Quality Management District's PM10-efficient sweeper certification.



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