ARE RAIN GARDENS MINI TOXIC CLEANUP SITES?

Here's what happens to the pollutants swept up in stormwater runoff.

Stormwater by Chesapeake Bay Program

Author: **Lisa Stiffler**
(@lisa_stiffler) on January 22, 2013 at 10:20 am

This article is part of the series Stormwater Solutions: Curbing Toxic Runoff

Oily puddle, Flickr user Banalities.

If you're concerned about water pollution, you've likely heard this message: The water that gushes off our roofs, driveways, streets, and landscaped yards is to blame for the bulk of the pollution that dirties Puget Sound and numerous Northwest waterbodies. You probably also know about the most popular stormwater solutions, including rain gardens and other green infrastructure that soak up the filthy water, cleaning it before it reaches sensitive waterways that are home to salmon, frogs, orcas, and other wildlife.

But those two ideas taken together are making some people anxious. If stormwater is the source of such devastating amounts of petroleum and heavy metals, won't the rain garden in my front yard become a mini toxic waste site that could harm children and pets?

So what exactly is in stormwater? Washington's Department of Ecology has identified runoff as the prime source of the mercury, lead, copper, petroleum and other dangerous chemicals getting into Puget Sound (Table ES-1).* Ecology officials estimate that more than 400 pounds of lead, for example, are being washed into Puget Sound via the stormwater that flows from residential areas.

By tonnage, though, the most significant stormwater pollutants are dirt, oil and grease, nitrogen-containing

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compounds and phosphorus — not the heavy metals and other stuff that's scarier from a human health perspective (Table 15). And for the pollutants that you wouldn't want to come into direct contact with — lead, cancer-causing petroleum pollutants, etc. — nearly all are found in super small concentrations in stormwater.

For residential runoff sampled in the Puget Sound area, pollutants in stormwater were below levels of concern for everything except PCBs and phthalates (a family of plasticizing chemicals added to countless consumer items including lotions, perfumes, and soft plastics such as shower curtains; Table 12), but even these were at tiny concentrations.

The problem isn't so much with the level of pollution in a given bucket of residential runoff, but the fact that the thousands of miles of roads and countless rooftops create so danged much of it. And yet the pollution is there, so what happens to it when it soaks into a rain garden or similar green stormwater infrastructure? Does it stay in the rain garden, or percolate through it along with the water?

The fate of stormwater pollution

Roadside rain garden in Seattle, Lisa Stiffler.

Scientists have answered the question of where runoff pollutants wind up through two types of experiments. They have sampled the runoff flowing into and out of actual rain gardens, and they've done laboratory experiments where polluted water is run through a column of soil analogous to a rain garden. (**I've listed many of the useful references that I've been able to find on stormwater pollution at the end of the post.)

The scientists found that the gardens do a great job catching metal pollutants and oil and grease — in some cases trapping more than 90 percent of the pollutants — keeping them out of streams and lakes where they harm wildlife and contaminate water for swimming, fishing, and other human uses. Rain gardens, often called bioretention systems, swales, or bioswales in the scientific literature, have a mixed record in terms of capturing bacteria based on tests done in the field.

Once the pollutants are trapped in the rain gardens, what

happens to them next?

The journal *Stormwater* published in June a list of possible fates for pollution in stormwater systems. Here's my adaptation of that list, edited to apply more specifically to rain gardens:

- **Volatilization.** Pollutants, particularly some of those associated with petroleum or oil and grease, evaporate.
- **Sedimentation.** In the case of standing water, heavier particles settle into the soil below.
- **Adsorption.** Certain dissolved pollutants stick to particles floating in the stormwater or settled into the soil.
- **Absorption.** Stormwater and pollutants soak deeper into the soil. Pollutants may accumulate in the soil, percolate through it with the water, or dissipate through microbial action, adsorption, or volatilization.
- **Microbial action.** Bacteria and other microorganisms break down pollutants in the water or soil, often into forms that are less environmentally harmful.
- **Plant resistance and uptake.** Decaying plant material increases adsorption and provides a good habitat for microbes that gobble pollution. Plants may also suck up pollutants from the soil through their roots, though not in large amounts.
- **Filtration.** Particles are captured by a filter, if one is present.

This is what can happen to the pollutants, but the question is what actually *does* happen? Let's look at petroleum chemicals, metals, and bacteria in turn.

Petrol pollution

Car exhaust, Flickr user eutrophication and hypoxia

One of the most prevalent categories of runoff pollution is oil and grease from leaking cars and spills at gas pumps, vehicle exhaust, and burning wood and fossil fuels. The contaminants include petroleum hydrocarbons, and a category of environmentally hazardous chemicals called polycyclic aromatic hydrocarbons, or PAHs.

Scientists with the University of Minnesota recently performed experiments in the field and the lab to track PAHs in stormwater systems. They collected more than 70 soil samples from more than 50 rain gardens and bioretention infrastructures in the Twin Cities. The rain gardens were capturing water from various types of land use, including parking lots, roofs, and streets. The researchers found much higher levels of petroleum hydrocarbons in the rain garden versus the non-rain garden soils, but the levels were essentially safe in both: "all soil concentrations were about one thousand times less than regulatory action levels," the scientists reported.

And what was even more interesting was the fact that the rain garden soil contamination was much less than they expected based on the volume of petroleum hydrocarbons being flushed into the gardens with the runoff. Where were the pollutants going?

To answer that question, the scientists did experiments with naphthalene, one of the PAHs found in rain gardens. They ran naphthalene-contaminated water through simulated rain gardens and discovered that the pollutant was adsorbed by the soil, biodegraded, or taken up by plants. The bottom line: "biodegradation typically destroys the contaminant, rather than simply retaining or transforming the contaminant."

Other studies similarly have found that bacteria in the soil of rain gardens like to dine on hydrocarbons. Research published in 2006 in the journal *Water Environment Research* found that 90 percent of petroleum pollutants were biodegraded by microbes in two to eight days.

And right here in the Northwest, the city of Portland's Bureau of Environmental Services has been doing its own testing of rain gardens and other green infrastructure to track pollutants. The bureau found PAHs at all of the rain garden facilities it tested, "but typically at concentrations well below human health guidelines." Interestingly, when they measured PAHs in non-stormwater soils next to the rain gardens, they found similar amounts of PAHs, suggesting that the pollutants are simply prevalent in many places in the urban environment.

Also keep in mind that many of the stormwater facilities tested by Portland were treating runoff coming from parking lots and roads that are being used by more cars

and trucks than your average residential site, so the pollutant loads could be higher than a front-yard rain garden would likely have.

CAN YOU EAT YOUR GARDEN VEGETABLES GROWN WITH RAIN BARREL RUNOFF? FIND OUT HERE.

Heavy metals

Spraying pesticides, Flickr user Bryan Gosline.

Heavy metals found in stormwater include copper, cadmium, lead, mercury, and zinc and come from a wide range of natural and human sources such as vehicle brake pads, aviation fuel, pesticides, and weathered paint. When runoff contaminated with metals streams into a rain garden, multiple studies show that the pollutants are largely adsorbed by particles in the soil and mulch. A small fraction of the metals are taken up by plants.

A 2007 study published in *Chemosphere* using faux stormwater contaminated with copper, lead, cadmium, and zinc in a lab simulation found that between 88 to 97 percent of the metals were captured in the soil media and up to 3 percent was trapped by plants.

But even if all the metals are being held in the rain garden, it's still not a large volume of toxics. A 2003 study concluded that it would take about 20 years for rain garden soils soaking up runoff to reach EPA limits for the amount of heavy metals allowed in recycled sewage waste

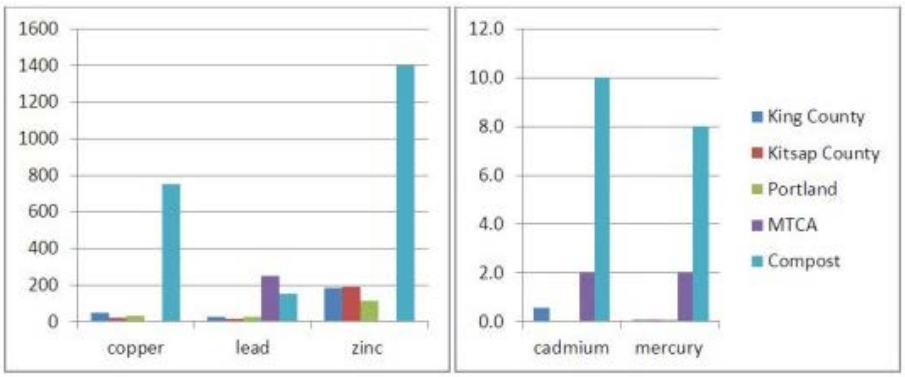
used as compost. Recent research from the University of Minnesota concluded that it would take 76 years or more for rain garden soils to reach saturation, depending on the heavy metal.

But does that mean a dog can safely dig in a rain garden, or a child can tromp through it without concern for their health (the fate of the plants put aside)?

Another way to parse the potential risk is to look at the metals in samples collected from local rain gardens and stormwater ponds. Again, the city of Portland has data from actual rain gardens and swales around the city. King and Kitsap counties in the Puget Sound region have data from the sediment scooped out of stormwater ponds. The ponds are not green infrastructure, are collecting runoff from roads that could have higher traffic than residential areas, and are not vegetated so they're less likely to be providing some of the natural pollution treatment that occurs in rain gardens. However, the ponds can still provide meaningful information, though their pollution levels could likely be higher than what you'd expect from a rain garden in front of someone's house that's capturing roof and residential street runoff.

Here are charts comparing the average concentrations of some heavy metals found in Northwest stormwater ponds and rain gardens. I've compared the amounts to Washington's cleanup standards under the Model Toxics Control Act. These are the cleanup standards for the soil at sites that can then be used for residential or other uses. I've also included the amount of pollution that is allowed in compost that can be used in Washington under the WSDA International Organic Program. Both provide benchmarks for what is considered safe to humans.

Metals in sediment from Northwest stormwater ponds or rain gardens, as compared to Washington safety standards for soil clean up and compost
(mg/kg dry weight)



King County data are average values from samples taken from four different stormwater ponds in 2011.
Kitsap County data are average values from multiple stormwater ponds sampled in 2009, 2010, and 2012.
Portland data are average values from 37 samples taken from the top 0 to 6 inches of soil in rain gardens and similar structures around Portland in 2010 (these values are approximate as they were extrapolated from a chart).
MTCA (Model Toxics Control Act) standards are Washington's contamination limits allowed for cleanup sites appropriate for "unrestricted use" (as opposed to industrial use).
Compost standards are limits allowed for manure used as compost in Washington under the WSDA International Organic Program.

As you can see, the amount of metal contamination in the stormwater ponds and rain gardens is well below safety standards used in Washington State.

Here are the data again in a table:

	King County	Kitsap County	Portland	MTCA	Compost
cadmium	0.6	0	NA	2.0	10.0
copper	49.1	23.3	30	NA	750
lead	28.3	13.8	25	250	150
mercury	0.1	0.04	0.05	2.0	8.0
zinc	187.3	188.6	115	NA	1400

Bacteria and viruses

No Dog Poop to drain, Flickr user Sweet One

Microorganisms in stormwater are eliminated numerous ways. An army of tiny creatures living in the water and soil including zooplankton, protozoa, nanoflagellates, microflagellates, amoeba, and bacteria will prey upon the offending microorganisms, which include viruses and other bacteria and protozoa. Sunlight can kill or inactivate some of the microorganisms.

Despite the numerous paths to destruction, microorganisms in stormwater are tricky. Unlike pollutants such as oil and grease and metals, green stormwater infrastructure doesn't have such a stellar track record for capturing and removing bacteria. It appears to be more readily destroyed when it's in the water, but more likely to survive in the soil. When researchers measure the amount of bacteria entering and exiting a rain garden out in the field, sometimes the water leaves the rain garden with even higher levels of bacteria than entered it, and in other cases 90 percent of the bacteria are removed. Some experts have suggested that the waste from birds, pets, and other wildlife recontaminate the water that's leaving

the rain garden.

Of course there are bacteria and other microorganisms everywhere, all the time, and most of them don't hurt people. So the real concern is whether the microbes washed into rain gardens pose an actual risk to humans. A lengthy 2007 study from the Water Environment Research Foundation (WERF) determined that bacteria and viruses that can make people sick have been detected in stormwater samples (Table 2-4). But when they tried to make a link between stormwater pathogens and actual cases of illness, the scientists concluded "the literature does not support widely applicable and defensible relations between pathogens and indicators in stormwater…" (page 2-13).

A Puget Sound area stormwater expert I spoke with explained the risk like this. If the water in question was coming from leaking septic systems or sewers, that waste would include human pathogens and bacteria and would be much more likely to cause illness in people. However, the bacteria found in stormwater most often comes from birds and wildlife, so the risk to humans is much lower.

Tallying the toxics

Rain gardens and similar environmentally friendly stormwater infrastructure are being embraced worldwide because they do their job so well. They sponge up polluted runoff, keeping the foul chemicals out of the places that are home to beloved wildlife and where people like to play and fish.

The worry is that these same, very efficient rain gardens that are cropping up in our parking strips and front yards are doing their job so well that they could become

residential toxic sites. But in fact are they? Not according to the research that's available. Here's the score on pollutants in rain gardens, in summary:

Petroleum pollutants/PAHs: Studies from the field and laboratory find that rain gardens do a great job of capturing petroleum pollution, and that the chemicals are largely eliminated when they're destroyed by bacteria in the soil.

Heavy metals: Soil and mulch in rain gardens contain particles that will adsorb and hold metals including copper, cadmium, lead, and zinc. A small fraction of the metals are sucked into plant roots and vegetation.

While metals are not degraded in rain gardens, they're present at very low levels. When Northwest counties test for metals in the sediment that's scooped from the bottom of stormwater ponds or rain gardens that drain parking lots and other city surfaces — material that would likely have higher levels of metals than your average residential rain garden — they found that the contamination levels were still below soil and compost standards meant to protect human health.

Bacteria and viruses: While some research has found bacteria and viruses that can cause disease in humans in stormwater, sunlight as well as other microorganisms in the runoff and soil of rain gardens can destroy the pathogens. Also, most of the microorganisms present come from animal waste and are less likely to cause illness in people.

The bottom line is that the soil in rain gardens is safe for kids and pets. That said, people are advised to wash their hands after working or playing in any soil, which can

contain naturally occurring metals, fecal waste from the neighbor's dog, or any number of compounds one wouldn't want to ingest. And remember that while rain gardens are attractive landscape features, the plants and soil are also doing an important job, so they need to be treated with some care.

Endnotes

*In recent years, Washington regulators have tried to identify the source and volume of pollution that fouls the Salish Sea, which stretches from southern British Columbia down through Puget Sound. They've released multiple reports on the issue, including "Control of Toxic Chemicals in Puget Sound" and "Toxics in Surface Runoff to Puget Sound: Phase 3 Data and Load Estimates." A great source from the first document is Table 30, which zeroes in on the specific sources of the pollutants, e.g. the top source of lead is "ammunition and hunting shot use, loss of fishing sinkers, loss of wheel weights."

**References for pollution removal, fate, and treatment include:

- "Bioretention Technology: Overview of Current Practice and Future Needs" by Allen P. Davis et al. published in the March 2009 issue of the *Journal of Environmental Engineering*
- "BMP Effectiveness for Nutrients, Bacteria, Solids, Metals, and Runoff Volume," by Jonathan E. Jones et al. published in the March-April 2012 issue of *Stormwater*
- "Capture and Release of Pollutants by Rain Gardens" by Joel G. Morgan et al. from the November 2011 issue of the Updates Newsletter from the University of Minnesota
- "Contamination of Soil and Groundwater Due to Stormwater Infiltration Practices: A Literature Review" from Peter T. Weiss et al. and published in June 2008 as a project report from the University of Minnesota

- "Development of a Protocol for Risk Assessment of Microorganisms in Separate Stormwater Systems" by Adam W. Olivieri et al. and published in 2007 by the Water Environment Research Foundation
- "Investigating Stormwater Hydrocarbon Fate and Biodegradation in Bioretention Areas" by Gregory H. LeFevre et al. from the April 2012 issue of the Updates Newsletter from the University of Minnesota
- "Review of Bioretention System Research and Design: Past, Present, and Future" by Audrey Roy-Poirier et al. published in the September 2010 issue of the *Journal of Environmental Engineering*
- "Sustainable Oil and Grease Removal from Synthetic Stormwater Runoff Using Bench-Scale Bioretention Studies" by Eunyoung Hong et al. from the February 2006 issue of Water Environment Research
- The Performance of Grassed Swales as Infiltration and Pollution Prevention Practices: A Literature Review" from Peter T. Weiss et al. and published in November 2010 through the University of Minnesota
- "2010 Stormwater Management Facility Monitoring Report" by the City of Portland's Bureau of Environmental Services, Tim Kurtz et al., and published in December 2010

Tagged in: Rain Garden, Stormwater, Toxics, Water pollution

Previous article in series:
« It Takes a Cluster to Build a Rain Garden

Next article in series:
Seattle's Green Stormwater Goals »

COMMENTS

Barry Tonning
January 22, 2013 at 11:37 am

REPLY

Very nice summary!

Thanks for sharing, and best of luck!

Rietha Crafford
February 7, 2013 at 8:35 am

REPLY

I am amazed that nobody has mentioned Vetiver Grass. It is such a good pollutant absorber and works wonderful, the young shoots can be used for foddr if on farmland and or for producing oil for extra income.....at the same time the roots will stabilize the soil and you will have no erosion. Who ever said you should remover the top layers of the soil every so many year, has got no clue what they are talking about. Firstly it is not feasible and secondly ou will end up with dead/poor quality soil eventually

Vetiver even absorbs and break oil pollution down.

Rietha

Steve Erickson
March 22, 2016 at 2:23 pm

REPLY

I am somewhat dubious that this species would grow in Washington, since its of tropical origin. Also, many of its characteristics are typical of very weedy species. If it did grow here I wold be really concerned about its potential to become invasive.

Cliff Aichinger
January 22, 2013 at 12:17 pm

REPLY

Excellent summary. You have summarized what I have

been saying for years, but many in our field still believe there is a problem with rain gardens. I am hopeful that this helps to allay some of those concerns. I will share you blog.

Andy Reese
January 22, 2013 at 2:09 pm

REPLY

Great summary – suitable for about everyone I know… and some I am only suspected of knowing!

Lisa Stiffler
January 22, 2013 at 2:38 pm

REPLY

Thanks for the feedback! And readers, let me know if you see something that needs refining. One suggestion I've had is to let people know that over time, it can make sense to remove the top few inches of soil in a rain garden to improve performance and eliminate metals that could be accumulating. Other thoughts?

Cari Simson
January 22, 2013 at 8:11 pm

REPLY

Thanks Lisa for this great summary. I've heard many questions about "where does the pollution go?", but had not found an easy-to-digest compilation like this. We appreciate your work!

Tom Ennis
January 22, 2013 at 9:27 pm

REPLY

Lisa:

I appreciate what you are trying to do, but in the process of distillation the discussion on PAH's is way oversimplified. The research that you quote out of

Minnesota used naphthalene as surrogate for all PAHs! Yikes that is taking the most easily broken down PAH and applying it to all others.

The heavier weight PAH's stick around for a long time (decades/centuries) but naphthalene is not among them. Do a bit more digging on this area.

Why does that matter? Look at the BILLION dollar cleanup predicted in the greater Minneapolis area from coal tar polluted stormwater ponds and you'll see the consequences of potent, long term, persistent PAH contamination and the potential to mushroom those costs with ill-advised BMP's.

Lisa Stiffler
January 23, 2013 at 10:22 am

REPLY

Hi Tom —

Thanks for the critical feedback, it's much appreciated. I'll keep poking around on the PAHs. The research I've looked at, beyond the Minnesota study, does seem to show that PAHs are broken down in rain gardens and similar situations, but I'll make sure they were measuring heavy and light PAHs.

I also wonder if the coal ponds are a slightly different situation because of the anaerobic conditions in a pond, as opposed to a bioswale?

Thanks again, and keep the comments coming!

Brian Issa
January 25, 2013 at 10:33 am

REPLY

Tom,
Having worked on PAH remediation in the past, I can tell you that even larger more stable chemicals like pyrene are broken down in an aerobic , biologically active environment. I worked on a superfund site in Montana contaminated with creosote where the soil was nearly sterile due to the amount of creosote present. I managed to isolate mycobacteria which were still able to break down pyrene even in this environment. The most cost effective remediation was land application, aeration, and time. I'm fairly confident that the low amounts of these more

stable PAHs present in stormwater will be broken down in a short period of time in a well vegetated bioswale.

Lisa Stiffler

January 25, 2013 at 11:00 am

REPLY

Fantastic two-cents, Brian. Thanks for giving your experience.

Greg LeFevre

January 29, 2013 at 1:58 pm

REPLY

Tom,

I am the lead author on the bioretention hydrocarbon work mentioned at the University of Minnesota. In our laboratory work, we did use naphthalene, which is often used as a model hydrocarbon (field investigations examined others). Nevertheless, we do NOT use naphthalene as a surrogate for all PAHs, and we EXPLICITY state this in our work.
Please see:
LeFevre, G.H. et al. Fate of naphthalene in laboratory-scale bioretention cells: Implications for sustainable stormwater management. Environ. Sci. Technol. 2012, 46 (2), 995-1002.

LeFevre, G.H. et al. The role of biodegradation in limiting the accumulation of petroleum hydrocarbons in raingarden soils. Water Res. 2012, 46 (20), 6753-6762.

Indeed, you are correct that high molecular weight PAHs are inherently more recalcitrant in the environment than low molecular weight PAHs. Nevertheless, many of the genes that encode for enzymes to initiate attack and ring cleavage on PAHs are somewhat non-specific and can thus catalyze degradation of multiple types of PAHs. Brian is correct when he states that PAHs degrade best in an aerobic environment.

This is exactly where your point of concern regarding PAHs in stormwater ponds is highly relevant. Because the bottoms of these ponds are often devoid of oxygen and anaerobic biodegradation of PAHs requires viable alternative electron acceptors or are degraded cometabolically, these reactions are have inherently long kinetic rates (i.e., they take a LONG time to degrade at the bottom of a pond). Thus, if the mass flux into the pond is greater than the degradation rate, accumulation occurs, as has occurred in the examples you cite. Our research shows that the conditions present in bioinfiltration systems are substantially more conducive for biodegradation as evidenced through field and laboratory investigations of specific target compounds. Given that the status-quo technology for

stormwater is the stormwater pond, we wanted to evaluate if green infrastructure alternatives (i.e., bioretention systems) performed better. Although we could not test every compound available and I am currently continuing work on a broader suite of organic pollutant classes, the results are robust for the experiments conducted.

The BEST and easiest way to reduce the further accumulation of PAHs in lake and stormwater pond sediments is source control, i.e., not using coal-tar based sealcoats. In addition to the disposal cost and ecological concerns, there are also human health impacts associated with coal-tar based sealcoats. This will be the best solution, and we will not have to worry about if they are accumulating in ponds OR raingardens.

Gregory H. LeFevre, Ph.D.
Postdoctoral Scholar, Environmental Engineering & Science
Department of Civil & Environmental Engineering
Stanford University

Susan Bryan
January 23, 2013 at 12:19 pm

REPLY

Thanks Lisa!

I wonder if you could take this line of questioning further and address a question I have received many times – twice in the last month!

Can you eat vegetables grown in a residential rain garden setting?

I have heard people say no, but is there evidence to back this up? And if only a small proportion of the small amounts of accumulated heavy metals are taken up, is it small enough to eat?

Many people use water from rain barrels to water their raised vegetable beds. Is this inadvisable? Or is it ok for roofs, but not driveways?

Lisa Stiffler

January 24, 2013 at 4:11 pm

REPLY

Oh my, this one is challenging. I know that in Seattle, folks with the city instruct people not to use their rain gardens for growing food.

Driveways and roads are clearly going to be a source of PAHs and metals and other petrol waste.

Most roofs are less innocuous than they might seem. The ubiquitous composite roofs are an asphalt product and I'm sure they leach PAHs, and some people treat their roofs with herbicides to kill moss. Not good stuff. I don't know if it would be OK to use runoff from a cedar roof or a metal roof — it would probably depend on whether the material had been treated with preservatives of some sort.

If we return to the original conclusion in the post that rain gardens are safe, why wouldn't they be safe for veggies?

I think there are a couple of reasons. While rain gardens can treat pollutants, it can take days or weeks for the pollutants to be broken down. Depending on when it rains and when you're harvesting food, you could be plucking lettuces that the day before were soaking in straight runoff. And yes, there is the potential for the plants to actually take up the pollution into their vegetation. It does appear to be a small amount in the studies I've seen, but this would vary by pollutant and plant.

In the past, I've been pretty vigilant about using my rain barrel water for ornamental plants, but not food (I sort of made exceptions for fruit trees, though I have no idea if that was wise!). Given the length of the droughts we experience in the Northwest in the summer, I find that I can completely deplete my rain barrel stash on non foods.

I hope this helps! I think I might just have to turn this response into another blog post and see if I can't find more data....

Jennifer

January 25, 2013 at 2:50 pm

REPLY

I participated in a great little webinar put on by Watershed Management Group http://watershedmg.org yesterday called Soil's Role in Processing Pollutants from Air and Water: Case Studies of Green Infratructure and Carbon Sequestration. They did mention that they studied the fruit from the plants

in rain gardens and that the levels found in them were nd or well below levels of concern. I don't think this applied to plants that would be saturated with polluted stormwater, i.e. lettuce.

Vincent Vizachero

January 30, 2013 at 5:46 am

REPLY

We have high levels of lead in our soil and the best data I could find suggested that root vegetables were a bad idea period. Leafy vegetables were probably okay if well washed. Fruiting plants (eg peas, corn, tomatoes, peppers) were not a problem.

Dave Peeler

January 23, 2013 at 12:42 pm

REPLY

Great article, should help to decrease homeowners' fears of raingardens. One issue that I have not seen covered in the press but is suggested by your comment regarding periodically removing the top few inches of soil, is that of raingarden maintenance. What can a homeowner expect in the way of maintenance needs on an annual basis as well as over 5, 10 or 20 years? Most if not all landscaping projects require some sort of care as time goes by.

Aaron Clark

January 23, 2013 at 4:03 pm

REPLY

I can comment on this excellent question, though it isn't a simple equation: Each rain garden is different and requires different levels of maintenance. In general what we find with those that we've built is that rain gardens require a modest amount of maintenance overall and most of that during the first 2 years after it's planted. It follows the general rule of "an ounce of prevention is worth a pound of cure." If you can stay on top of basic weeding, say an hour or two a month, for those first two years, the rain garden plants can get well enough established to prevent most new weeds from taking root. Re-applying mulch, especially during the first 2 years is also advised and doing some watering when things get dry in the summer (again mostly in the first 2 years)will help ensure a vigorous, low maintenance garden. Our team of WSU Master gardeners, myself and Cari Simson who commented above are developing some simple guidelines and maintenance materials for this

region that will be coming out in the next year or so. In the meantime some good advice is printed in the Western Washington Rain Garden Handbook available here (see pages 37-39):
http://county.wsu.edu/mason/nrs/water/Documents/Raingarden_handbook.pdf

Lisa Stiffler

January 24, 2013 at 4:14 pm

REPLY

I also wonder if by adding mulch each year or every couple of years if that buries soil that might be accumulating metals? Thoughts, anyone?

Mark Early

January 12, 2014 at 7:27 pm

REPLY

I've heard from a consultant in enviro design (teaches masters level classes at University of WA environmental science dept) that in Germany they are removing the top several cm's of roadside raingarden bio-soil every 4-5 years. Hauling it to a landfill certified to accept toxic waste. I am tracking down the original sources of that information at this time.

Years ago I read the big WERF study the author of this article cites; DEVELOPMENT OF A PROTOCOL FOR RISK ASSESSMENT OF MICROORGANISMS IN SEPARATE STORMWATER SYSTEMS (2007). Some of the troubling case studies under review by the prestigious WERF research team are located here in the NW. I visited one myself in Montlake Terrace WA and have ask a family friend; a retired research scientist on infections diseases (from CDC and Fred Hutch Cancer Center), to review the report and help clear up any amateur miss-interpretation on my part.

Wished I shared this authors assessment, but my reading of the WERF report suggests that pathogens in bio-swales can multiply instead of diminish in concentration. This is rather disturbing. The researchers discovered bio-ponds, RG's do not behave at all like standing water marshes, which was the prior prevailing industry assumption. Marshes "deactiveate" (kill) pathogens in a variety of ways not available to raingardens; water column is clear in a marsh allowing UV to play a role, but cloudy in RG's protecting pathogens from both UV and attack from some microbes...etc. In raingardens pathogens can slowly multiply in merely damp soil, somewhat dormant in dry, and get re-introduced in larger concentrations into the water column during the next storm event with sufficient soil layer shear action. A decade ago, little Montlake Terrace water dept discovered as much and decided not to build a second phase

bio-swale next to a children's play area.

I would like to see more studies by organizations not tied financially to GSI promotion before making up my mind on this important topic. Not saying there was overt wrongdoing by researchers cited in this article (in fact I'm reading all of the material she mentions), but those of us who have worked for large technology firms or governmental orgs can attest to subtle but real effects of institutional bias on report outcomes. What data wasn't considered relevant, how experiments are setup, under-reporting of conflicting data...etc. These are important factors. WERF researchers found some of these same institutional processes kept many pathogen case studies hidden in plain sight until enough anecdotal evidence prompted their research. The report was paid for by one of THE large water industry trade associations, so it's best to read the entire report and not accept a few sentences penned by one of the dozen or so researchers as definitive of the group's at times nuanced conclusions.

Merritt Scott (Rusty) Miller
January 24, 2013 at 4:17 am

REPLY

Lisa, another outstanding example of "green" journalism and one I'm passing along to the readers of The Northstar Journal. Way to go, girl. You rock. Rusty

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civiletti
January 25, 2013 at 11:35 am

REPLY

I'm wondering if the level of metals allowed in compost is influenced by the wastewater industry's desire to spread sewage sludge on ag land.

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virginia rockwell, VSLD, VCH
January 28, 2013 at 7:04 am

REPLY

great answers to anxious questions from homeowners and others. may i please use some of this content here in the Chesapeake Bay region when I give a talk at Lewis

Ginter Botanical Garden on 2/14 at the Central Virginia Nursery & Landscape Association's Winter Symposium? The talk is entitled 'Apply Brains first, Fertilizer ONLY as Needed" about all the existing practices we can use to prevent polluted runoff from reaching our children's streams, rivers and the Bay.

thank you! let me know if you have any of this on SlideShare.

Lisa Stiffler
January 29, 2013 at 10:21 am

REPLY

Yes, you can definitely use this content, and thanks to everyone who has inquired about doing so. We ask that you give me and Sightline credit when you do. Here is a link to our policy on reuse. Also feel encouraged to email me directly — I've created a summary of the post if people want to include it in newsletters.

Dan Medina
January 28, 2013 at 7:47 am

REPLY

Great summary Lisa. I've tracked these findings for years and they are consistent in their conclusion that fears of mini-superfund sites in everyone's yards are unfounded. Additional references are cited in Manual of Practice No. 23, Design of Urban Stormwater Controls, published by the Water Environment Federation and the American Society of Civil Engineers.

Lisa Stiffler
January 29, 2013 at 10:11 am

REPLY

Thanks for the confirmation, and I'll check out this resource.

Jeremy Gye
January 28, 2013 at 9:11 am

REPLY

Thanks for this very useful summary and the associated

comments everyone. One useful context piece missing from this conversation is the move in many communities toward using bmps, such as raingardens, to manage rainwater where it falls. This disperses the collection points for rainwater and pollutants, whereas older stormwater management models tend to concentrate it in receiving waters. From this perspective, increasing the perviousness of the catchment areas within our urban watersheds is a key strategy.

Leonora
January 28, 2013 at 10:52 am

REPLY

Great information, thanks!

A question from a non-techie: does anyone have any thoughts on whether the beneficial impacts of raingardens are greater (a) if dispersed via smaller gardens on residential lots throughout a large neighborhood, or (b) if concentrated in 2 or 3 larger projects (e.g. in a park) in that same neighborhood?

Our municipality is the only one in our county (mid-Atlantic region) that does not provide funds for residents' stormwater-catchment efforts. The apparent reason is that the municipality already has such an effort – but it's focused on a few public projects. I'd like at least some of those funds to be available for residents to use, because #1 I think it could have beneficial impact by spreading efforts throughout the municipality, and #2 I think the PR/public education would have greater impact.

However, I have no idea if there are any general data available that investigate such a comparison; I could be completely wrong. Any thoughts? Or suggested resources? Thank you!

Dr. John L. Gardiner
January 29, 2013 at 10:13 pm

REPLY

This is a complex question, because of the varying conditions found in the average catchemtn/watershed. In the UK, the Subsidiarity Principle is used as general guidance. This means that where source control is practicable, it should be applied; green roofs, rainwater harvesting and raingardens for example. Because thes techniques are not always practicable, the next 'line of defence' is the site or sub-division; so infiltration devices (including swales) will catch what is not treated by source control, at or near the point of rainfall. Exiting from the site or sub-division, the next controls may be vegetated storage (bioremediation) ponds that can be cleverly designed for flood risk reduction while providing the required residence time for bioremediation (mostly, suspended sediment removal). Finally, as Tennesee Valley Authority reasoned, damming the tributaries to control the flow into the mainstem was regarded as the efficient way to keep flood risk within acceptable limits while producing electricity. Taking this last step today would be an admission of failure to manage stormwater in the river basin. The goal is to push for true source control, thus containing the social and environmental costs within the development area, rather than externalizing them as was the traditional approach.

Ben Alexander

January 31, 2013 at 12:57 pm

REPLY

The benefits provided by rain gardens vary according to the site scale and the types of problems that occur at any given site. Non-point pollution that originates from human activities widely dispersed across the landscape is the hardest to control. Rain gardens dispersed throughout residential and commercial areas offer an important tool for reducing non-point pollution,in areas where non-point pollution is a problem. Of course, if non-point pollution is not a big issue where you live, then you will get less benefit from a rain garden. Rain gardens are less likely to improve problems related to water quantity, such as erosion and flooding, because they are caused by a high proportion of impermeable surfaces within the drainage basin or watershed. At some vague point, vegetated stormwater facilities become too large to be considered "rain gardens" because the amount runoff entering them changes the way they function – the precipitation does not infiltrate quickly enough, influencing the type of vegetation that can survive there.

In my neck of the woods (Pacific northwest), rain gardens are being used primarily in two ways. Homeowners are installing them on their lots to deal mainly with roof runoff from downspouts, and some cities are installing them in public

rights-of-way to treat road runoff. Portland, Oregon has been particularly aggressive with this approach. The publicly-owned facilities tend to be somewhat larger, and more prone to sedimentation, than the residential facilities. The public facilities will probably have more demonstrable benefits because they treat runoff that would otherwise enter the storm drain system and flow into a reeving water body where you can measure the water quality. The benefits from many small residential rain gardens will be much harder to quantify.

Nathan

February 6, 2013 at 1:12 pm

REPLY

I think it's worth pointing out that your municipality's project might be managing stormwater for a larger area than you think. Public projects can use pipes to drain runoff from adjacent areas while also managing direct infiltration, where a residential raingarden might only manage the rain that falls directly on it. For example, where a 10'x6' residential raingarden manages all the runoff from your backyard, a 10'x6' municipal stormwater planter can be engineered to manage runoff for an entire city block. Those extra engineered features aren't always easy to see.

Mark Early

January 12, 2014 at 6:30 pm

REPLY

In Seattle our water department is pushing both public ROW and private roof capture raingardens. One document from them that is not generally discussed (WA State SPU SEPA form) admits when too many private (or public) raingardens are built over our Seattle glacial till soils it may cause an increase in perched water problems. Translation – injecting thousands of gallons of new stormwater into the ground in residential neighborhoods leads to an increase in leaking basements (most of Seattle homes like ours have basements).

In 2010 this same SPU department ignored 32 soil tests (26 trench tests and 6 deep bore) it's contractor performed in my Ballard neighborhood and build 93 roadside bio-retention cells (weir divided portions of RG's) detention capacity 50,000 gallons, over mostly glacial till at a cost of $1.7 million. Predictably many of the cells failed to drain… at all.. over many weeks, resulting in a public relations nightmare.

In a cynical PR solution SPU filled in the cells with loads of bio-soil, more plants and announced it had solved the problem. Well, no more muddy ponding, but now the RG's didn't provide much measurable stormwater detention to address CSO

events in our basin. And CSO is definitely a problem we must solve to save Puget Sound. Residents were so upset that SPU would not re-design the roadside RG's to both address ponding and provide CSO mitigation that 1/3 of the RG's had to be removed entirely at a cost exceeding $350,000. The remaining RG's are for show; negligible rain event detention/diversion capacity, basically self watering roadside public landscaping. Very sad.

My point being, stormwater usually goes where it wants, sometimes creating unintended consequences where public RG's are installed over poorly draining soils. Make sure your neighborhood residents get to see the original soils tests, not the sanitized results our water dept offered and then actually ignored. GSI advocates can be blinded by good intentions the public later pays dearly for.

Bill Dunbar
January 28, 2013 at 1:10 pm

REPLY

Excellent piece...as usual. It'd be great to know which native non-food plants do the best job of capturing pollutants. For instance, i don't use my rain barrel water fro fruits and veggies, but would happily swap out ornamental plants for better "filterers" at the end of the pipe.

Hope you're great!

Lisa Stiffler
January 29, 2013 at 10:16 am

REPLY

Oh, Dunbar. Did you have to pitch me a zinger?! It's a great question, and I'll hunt around for an answer if it's out there. I'm doing very well, thanks, and hope you are too.

Rhonda Morgan
January 29, 2013 at 2:02 pm

REPLY

Although geared toward larger contaminated site remediation issues, ITRC (Interstate Technology & Regulatory Council) Phytotechnology Technical & Regulatory Guidance includes a "Database of Contaminant Remediation by Plants" in

Appendix B. The listing includes some interesting information about several edible plants as well. Good bibliography, too.

http://www.itrcweb.org/Guidance/ListDocuments?TopicID=20&SubTopicID=30

Alison Gillespie
January 29, 2013 at 5:09 am

REPLY

This is a fantastic article. I appreciate the detailed science round up and I will be sending others here for the information.

Some of the other comments touch on the topic of roofs and veggies. Like you, I do not use the water gathered in my rainbarrels on my edibles. (See comment from Susan Bryan.) I have heard this topic hotly debated but not seen any science on the topic. One of the things that seems to make it tough to gather data is the huge number of variables in roof designs, and roofing materials.

Have you seen any solid science on that topic?

Lisa Stiffler
January 29, 2013 at 10:14 am

REPLY

I am working on a follow up post to address this, but the data seem woefully limited. Stay tuned!

Doug Pineo
January 31, 2013 at 11:37 am

REPLY

Excellent work interpreting the technical literature, Lisa. Also, a great subsequent discussion.

As Dave Peeler knows, the “208” swales (from Section 208 of the federal Clean Water Act) were pioneered, among other places, in the Spokane area of eastern Washington. Decades later, urban and suburban landscapes of the Spokane area are pockmarked with the now familiar

"concave lawns" of 208 swales.

Meanwhile, rain gardens have proliferated in the upper midwest, east coast, and the Portland and Puget Sound regions, among others. Some opportunities for rain gardens are not generally addressed among planners, local governments and water quality agencies or in the literature. these include potential benefit from establishing native woody plant communities in both residential and commercial rain gardens, for resident and neotropical songbirds, and landscape architectural opportunities in urban environments. Once established, natives also require much less maintenance than turf grass or most other non-native plant assemblages.

Another question hard to find addressed in the literature, is the potential difference in PAH, metals and pathogen remediation, between rain gardens west and east of the Rockies. This might be because rain gardens in the semi-arid intermountain west are so recent and few.

Most of the annual precipitation falls in the high plains, midwest and eastern states during the growing season of spring and summer. West of the Rockies in the Northwest, the large majority of our moisture is received from October through March.

Over 26.4 inches of Seattle's annual average precipitation of 36.22 inches (72.9%) falls in October through March. In contrast, at Bozeman, Montana, 12.88 inches (62.22%) of the 20.7 inches of average annual precipitation falls from April through September. Monthly average precipitation in the central Montana region in July and August is almost twice that of Seattle, and almost three times higher than Spokane. In Minneapolis, the average annual precipitation is 31.3 inches, of which 21.69 inches (69.2%) of annual average, falls from April through September. Average precipitation for August in Minneapolis is 4.30 inches, well over 7 times more that Spokane's August average of 0.59 inches.

Evapotranspirative potential in plants, yielding from interactions of the temperature pressure gradient, plant metabolism, growth and species, as well as climate, incorporates another group of variables. Testing for these variables may yield significantly different results for remediation of pollutants by biofiltration swales and rain gardens in different parts of the country.

Nathan
February 6, 2013 at 1:12 pm

REPLY

I think it's worth pointing out that your municipality's project might be managing stormwater for a larger area than you think. Public projects can use pipes to drain runoff from adjacent areas while also managing direct infiltration, where a residential raingarden might only manage the rain that falls directly on it. For example, where a 10'x6' residential raingarden manages all the runoff from your backyard, a 10'x6' municipal stormwater planter can be engineered to manage runoff for an entire city block. Those extra engineered features aren't always easy to see.

Laura Tam
February 7, 2013 at 1:42 pm

REPLY

Thank you for this very comprehensive look at an issue that has been raised here in San Francisco as we embark on trying to put more green infrastructure in our severely hardened streetscapes! To me, this part was discomfiting: "A 2003 study concluded that it would take about 20 years for rain garden soils soaking up runoff to reach EPA limits for the amount of heavy metals allowed in recycled sewage waste used as compost. Recent research from the University of Minnesota concluded that it would take 76 years or more for rain garden soils to reach saturation, depending on the heavy metal." 20 years (or even 76 years) are not that long in terms of a house's or a neighborhood's life and even if the green infrastructure is

long gone, the metals will still be concentrated there, right? The examples you go on to mention comparing levels of pollutants in the not-green-infrastructure stormwater pond water vs. compost do not say how old those ponds were, or if the measured sediment concentrations tended to remain constant over time (like we would expect compost to). Although the conclusion that the fate of organics and pathogens is short term in dispersed green infrastructure (yay) – long term metals accumulation seems kinda worrisome. Am I missing something?

Lisa Stiffler
February 7, 2013 at 3:57 pm

REPLY

Great questions!

The ponds are being dredged annually, though again, they are getting much larger volumes of runoff from more heavily trafficked surfaces than your residential rain garden would. They represent a worst, worst case scenario by comparison.

The metal pollutants do accumulate over the course of decades, but I don't think that argues against installing residential rain gardens. First, it would be pretty straightforward to remove the top couple of inches of soil perhaps every 10 or 20 years and replace it. Alternately, I wonder if it would be effective to keep adding mulch each year or two, and if that would dilute the pollutants or send them deeper over time; if someone can weigh in on that, I'd love to know what effect regularly adding mulch would have.

A key point to keep in mind is that rain gardens are stormwater infrastructure that require some maintenance just like pipes and holding tanks. I haven't seen studies comparing rain gardens that capture roof runoff vs those in the public right-of-way that capture road runoff, but I presume the latter is going to be more polluted with metals in most cases, and require more maintenance to address those issues. The matter of who maintains ROW rain gardens appears generally to fall to the government that owns the land, but the level of maintenance varies and is still being sorted out in many areas.

Also, if residents are concerned about what could be building up in their rain gardens over time, particularly if they have kids

who could be getting into the gardens or if they're planning to do work in them, there are numerous labs that will test the soil for contaminants. The University of Massachusetts at Amherst will do the test for $10, and you can also check your local cooperative extension branch to get information on tests available in your area.

I hope this helps. And again, if someone else has more or different or even contradictory info to add, please do so!

Tom
February 8, 2013 at 6:47 am

REPLY

Thank you for the informative article and the even more informative discussion afterwards. I feel like one central point was glossed over, though:

If the pollutant buildup from concentrated runoff getting into rain gardens is truly small and nothing to worry about, why is it a problem for the runoff to get into Puget Sound in the first place? Puget Sound is much bigger than the cumulative rain garden area, so pollutants should be even more dispersed.

I think I know where this logic is flawed, but I wonder if it's not worth amending the article to clarify.

Rich Tyas
December 24, 2013 at 6:40 pm

REPLY

I'd like to know where you think the logic is flawed, Tom. If you have time to explain your view, I'd be so pleased to look through your informed lenses.

Steve Hitch
February 26, 2013 at 9:50 am

REPLY

Thank you for this great piece of work. I think bioretention and rain gardens require careful study.

Fate of pollutants is an area that has not had enough focus. Many of the monitoring projects I have seen identify pollutant removal rates by measuring the surface water flowing in and the surface water flowing out, ignoring the water infiltrating into the groundwater. My concern has been the water infiltrating that carries nutrients, metals, pesticides, and PAHs into the groundwater. (Fortunately, most stormwater pollutant concentrations are low enough that they will not exceed groundwater quality standards.)

Plant and soil management can make a difference in the fate of those pollutants, too. Are the plants in the bioretention cells woody accumulators of pollutants or are they leafy grasses that collect pollutants in the summer and then die back to release the pollutants in the winter? Are leaves removed from cells or allowed to decompose?

Another area that has been ignored is the export of pollutants from bioretention. Studies that monitor the water quality of all the discharges from bioretention show significant export of pollutants like nitrates and copper.

More research is needed on performance of bioretention with various media and climates. I think we are learning that one size does not fit all climates or locations. Stormwater if allowed to infiltrate into the ground may have less impact on the groundwater quality than if it is routed through a bioretention cell.

Bioretention holds the promise of on site stormwater management and can be an important key to addressing hydrologic impacts to streams. The important step we need now is full scale testing of bioretention for water quality (nutrients in the case of groundwater discharge; copper and zinc in the case of underdrain discharges to surface water).

Anonymous
September 10, 2013 at 1:54 am

REPLY

Like many commenters, I, too, am curious about using rainwater on vegetable gardens. Is there conclusive evidence showing that rain gardens are safe?

Lisa Stiffler
September 10, 2013 at 7:00 am

REPLY

Great question! That's an issue on my fall to-do list. I don't know that there are specific studies, so I might need to enlist the help of botanists to sort it out.

Evan Pratt
May 2, 2014 at 12:41 pm

REPLY

I do not have the specific data citations, but understand there has been research on fungi that reportedly demonstrates their ability to assist with soil and water conservation. Without getting into all the toutings, for purposes of this article, the PhD researcher I spoke with indicated that Oyster mushrooms have been proven to process not only hydrocarbons, but also PCB's – without having traces in the mushroom, so it would still be edible. If that is true, perhaps there could be or has been study on fungi w/r/t the tougher PAH's like coal tar.

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jerome parker
January 8, 2015 at 11:14 am

REPLY

I missed this article when it was published. It is an amazing piece of work. It makes me doubly glad I contribute to Sightline!

Dan D. Wrye
March 22, 2016 at 12:29 pm

REPLY

Thank you for the well-researched and presented article on polluted runoff. With so much focus on the "toxics effects of stormwater" in the media over the past few

years, many of us in the profession have been concerned that this focus will lead to treatment technologies and costs that are designed for worst case scenarios when simple solutions are what is needed. And we have been concerned that the public may fear stormwater rather than look at it from a "one water" perspective, as a resource for wetlands restoration, groundwater recharge or irrigation. Your article clearly shows not all stormwater is "toxic" and should be shunned. It may deviate from the image of dead salmon or oil tanker spills created for political or media reasons but it is much more accurate to tease out the quality of stormwater based upon the sources contributing pollutants to it. Clearly, the data show a major difference in the quality of runoff from residential, commercial, industrial and major highway sources. Thank you.

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