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| To / Contact info | | Anne Gelbmann |
| Cc / Contact info | | Mike Trojan |
| From / Contact info | | Meghan Funke, PhDPaula Kalinosky |
| Regarding | | Task G. Human Health and Environmental Risks |

The construction and operation of stormwater harvest and use systems can pose potential risks from the pollutants and toxins found in stormwater and harvest and use system materials. These risks are largely addressed via water quality standards, plumbing and building codes, stormwater rules and regulations, required signage, and the engineering review process. Stormwater harvesting is, however, an emerging practice in water resource management and existing regulations may not fully address the risks associated with harvest and use practices.

Therefore, a risk assessment should be completed during the [pre-design phase] to ensure that potential risks are properly managed through system design, operation and maintenance. According to [U.S. EPA](https://www.epa.gov/risk), there are two types of risk assessments:

1. A human health risk assessment, which is the process to estimate the nature and probability of adverse health effects in humans who may be exposed to chemicals in contaminated environmental media, now or in the future.
2. An ecological risk assessment, which is the process for evaluating how likely it is that the environment may be impacted as a result of exposure to one or more environmental stressors such as chemicals, land change, disease, invasive species and climate change.

The following factors should be considered when assessing human health and ecological risks of stormwater harvesting and use systems ([NAS, 2016](http://www.nap.edu/catalog/21866/using-graywater-and-stormwater-to-enhance-local-water-supplies-an)):

* Geology and climate of the harvesting site
* Potential environmental hazards located within the rainwater/stormwater source area
* Source water quality
* Potential exposure to harvested water (indoor/outdoor, restricted access, unrestricted access)
* End use of harvest water

Potential human health and environmental risks of stormwater harvest and use systems, and ways to manage those risks through design, operation and maintenance are summarized briefly below. For further guidance, refer to Chapter 5 of [Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs, and Benefits](http://www.nap.edu/catalog/21866/using-graywater-and-stormwater-to-enhance-local-water-supplies-an) (NAS, 2016) and the [US EPA Risk Assessment](https://www.epa.gov/risk) webpage.

Specific guidelines for addressing health and environmental risks associated with stormwater harvest and use systems have been developed in Australia. See Figure 1.1 on page 6 of the [[Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2), Stormwater Harvesting and Reuse](https://www.environment.gov.au/system/files/resources/4c13655f-eb04-4c24-ac6e-bd01fd4af74a/files/water-recycling-guidelines-stormwater-23.pdf)] for a flow-diagram guide to their risk assessment approach.

# Human Health Risks

Human health risks include any adverse health effects in humans who may be exposed to chemicals in contaminated environmental media, now or in the future. Potential hazards to human health from stormwater harvest and use systems include:

* Chemical pollutants and pathogens in stormwater before and during harvest. This includes
	+ nutrients, sediment, microbes, salts, oil and grease, and metals typically found in stormwater runoff [Water Quality – Pollutants in Stormwater Runoff]
	+ Pollutants associated with spills
	+ Metals or other chemicals leaching from rooftops, conveyances, or tanks
* Bacteria or other pathogenic organisms colonizing in the collection or storage systems
* Waterborne diseases
	+ Bacterial pathogens (e.g., Escherichia spp., Salmonella spp., Campylobacter spp., Legionella sp.)Parasites (helminths)
* Opportunistic pathogens (e.g., Mycobacteria spp., Pseudomonas spp.)
* Mosquito-borne diseases (e.g., West Nile virus, La Crosse Encephalitis)

## Potential Exposure and Health Effects

The main health concern with harvest and use of stormwater is exposure to pathogenic microorganisms. Studies have consistently reported high concentrations of fecal indicator microorganisms across different source areas of stormwater; however, the occurrence and fate of human pathogens in stormwater is not well characterized ([NAS, 2016](http://www.nap.edu/catalog/21866/using-graywater-and-stormwater-to-enhance-local-water-supplies-an)). The nature and severity of human health effects depend on the type of exposure (skin contact, ingestion, inhalation, etc.) as well as the duration and magnitude of exposure (Table 1). Treatment requirements will be stricter for beneficial use applications which have a high chance of exposure compared to those which have a low risk of exposure. Additional information on exposure and dose-response assessments can be found on the EPA [Human Health Risk Assessment](https://www.epa.gov/risk/human-health-risk-assessment) webpage. This webpage also provides detailed guidance on how to complete the following steps of a human health risk assessment:

* Planning and Scoping process, which includes the following questions:
	+ Are there hazard(s) of concern?
	+ What is the source of the hazard(s)?
	+ How does exposure occur?
	+ Who/what is at risk?
	+ When/where are they at risk?
	+ What are the biological pathway and health effects of the hazard(s)?
	+ Under what conditions is a harmful effect likely to occur?
* Step 1 - Hazard Identification: Examines whether a stressor has the potential to cause harm to humans and/or ecological systems, and if so, under what circumstances.
* [Step 2 – Dose-Response Assessment]: Examines the numerical relationship between exposure and effects.
* [Step 3 – Exposure Assessment]: Examines what is known about the frequency, timing, and levels of contact with a stressor.
* [Step 4 – Risk Characterization]: Examines how well the data support conclusions about the nature and extent of the risk from exposure to environmental stressors.
*

Table 1. Examples of potential exposure types and pathways ([NAS, 2016](http://www.nap.edu/catalog/21866/using-graywater-and-stormwater-to-enhance-local-water-supplies-an))

| **Exposure Types** | **Exposure Pathways** |
| --- | --- |
| Skin contact | * Hand watering with harvested stormwater.
* Contact with irrigation mist or runoff
* Contact during use (washing, flushing)
* Contact during recreation
 |
| Direct ingestion | * Cross-contamination of drinking water supply with harvested stormwater
* Ingestion of irrigation mist or spray
* Ingestion of irrigated fruits and vegetables
 |
| Indirect ingestion | * Ingestion of bio-accumulated pollutants in food crops irrigated with harvested water
* Ingestion via hand-to-mouth after contact with irrigated areas
 |
| Inhalation | * Irrigation mist
* Water agitation
 |

# Ecological Risks

Ecological risks include any impact on the environment from the result of exposure to one or more environmental stressors such as chemicals, land change, disease, invasive species and climate change. Potential ecological risks from stormwater harvest and use systems include impacts to:

* **Plants** – Pollutants found in stormwater runoff (e.g., heavy metals, salts, and hydrocarbons) may decrease the productivity of or even kill certain plant species under high irrigation rates or long-term exposure from irrigation ([EPA, 2012](http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf); [National Academy of Sciences](http://www.nap.edu/read/21866/chapter/7#131) (NAS), 2016). The Minnesota Stormwater Manual lists [plant species with known tolerance to salt](http://stormwater.pca.state.mn.us/index.php/Minnesota_plant_lists). These species may also have some tolerance to sediments and petroleum which are commonly associated with salt in road runoff. Salt tolerance has also been shown in some of the aggressive and invasive species found in the Midwest. One concern with using stormwater for irrigation is that the higher pollutant loads will increase susceptibility to exotic and invasive species, such as common buckthorn, box elder, and reed-canary grass. ([MPCA](http://stormwater.pca.state.mn.us/index.php/Minnesota_plant_lists))
* **Soil** - Salinity in stormwater is a key concern for soil health. Sodium in harvested stormwater that is applied for irrigation can replace calcium and magnesium in soils. Over time, this process can negatively impact soil structure, making the soil less permeable and more erodible, particularly soils with high clay content ([NAS, 2016](http://www.nap.edu/read/21866/chapter/7#131)).
* **Local hydrology** – Stormwater harvest and use systems can impact local hydrology via ([US EPA, 2012](http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf)):
	+ increased baseflow to surface waters if extensive land application of water increases groundwater elevations,
	+ increased runoff volumes or peak rates during wet periods if extensive land application of water shifts soil conditions from ‘dry’ to ‘wet’ preceding rainfall events, and
	+ decreased local flow due to harvested stormwater for indoor uses being routed to the sanitary sewer system instead of discharging to surface waters.
* **Equipment degradation** - Some [stormwater quality constituents] can negatively affect the performance of the harvest and use system increasing maintenance needs and potentially reducing the useful life of components. [Stormwater quality] should be characterized in the [pre-design phase] so that design choices optimize performance of the system. Ultimately, a system that does not perform as intended may pose risks to health or to the environment. The stormwater quality constituents that could affect the operation of the harvest and use system equipment and structures include (from Toolbox R.1a in the [2011 Met Council Reuse Guide](http://www.metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning/Studies-Projects-Workgroups-%281%29/Completed-Studies-Projects/Stormwater-Reuse-Guide.aspx)):
	+ Debris and particulates associated with sediment and leaves could potentially block or clog pipes, irrigation nozzles or drip irrigation systems, or damage pumps.Organic matter (measured by BOD, COD, or TOC), for example from glass clippings, that causes reduced dissolved oxygen levels through decomposition could result in odors and release of pollutants from sediments.
	+ Nitrogen and phosphorus could support algal growth in open storage facilities, which can lead to higher turbidity and/or create algal blooms with biofilm characteristics that could clog irrigation equipment.
	+ Iron concentrations could clog irrigation systems and decrease the effectiveness of the disinfection system.
	+ Hardness could result in clogged irrigation systems.
	+ Anaerobic conditions or high salt concentrations could result in corrosion of system components.

# Managing Risk

Potential risks must be managed through proper design, operation, and maintenance of stormwater harvesting systems (Table 2). If potential risks cannot be addressed through cost-effective [design] or [operation and maintenance], the goals and objectives of the stormwater harvest and use system should be reconsidered in the [pre-design phase].

Table 2. Elements of design, operation, and maintenance that address potential risks associated with stormwater harvesting and use.

| **Risk Type** | **Design Considerations** | **O & M Considerations** |
| --- | --- | --- |
| **Human Health Risks** |
| Source area pollutants | * Bypass runoff from pollutant hotspots in the source area
* Pre-storage treatment and treatment systems
* Source control BMPs
 | * Inspection and maintenance of source area
* Regular clean-out of accumulated sediments in storage ponds, if applicable
 |
| Hazardous spills in the source area, including sudden air releases of hazardous substances that could deposit in the collection and storage systems | * Incorporate at least a 72-hour residence time of harvested stormwater in storage unit to contain hazardous spills in the source area prior to distribution ([NRMMC *et al.* 2008](http://www.environment.gov.au/system/files/resources/9e4c2a10-fcee-48ab-a655-c4c045a615d0/files/water-recycling-guidelines-augmentation-drinking-22.pdf))
* Incorporate an emergency bypass in the collection system
 | * Regular inspection of source area for hazardous spills
* Coordination with local agencies responsible for responding to hazardous spills in the source area
* Incorporate an emergency spill response plan in the O&M document
 |
| Metals and other chemicals from roofing materials (link to table 4 in WQ considerations)  | * Some roofs may leach chemicals at levels of concern
 | * Regular inspection and cleaning of system components to prevent degradation
 |
| Bacteria, viruses | * Source control BMPs
* Disinfection or filtration treatment systems
 | * Regular cleaning and maintenance of storage and treatment units
* Water quality monitoring
* Signage and/or access restriction to irrigation areas or other exposure controls
 |
| Mosquito and other vector-borne illnesses | * Install insect screens on exposed pipe and other openings
* See the following websites for information on mosquito control in storage ponds:
	+ [UC-IPM](http://www.ipm.ucdavis.edu/PMG/PESTNOTES/mosquitostormwater5.html)
	+ [MPCA](http://stormwater.pca.state.mn.us/index.php/Mosquito_control_and_stormwater_management)
 | * Regular monitoring
* Regular mosquito control treatment of storage unit
 |
| **Ecological Risks** |
| Plant communities | * Source control BMPs
* Pre-storage treatment and treatment systems
* Use of [salt tolerant](http://stormwater.pca.state.mn.us/index.php/Minnesota_plant_lists) plant species in irrigated areas
 | * Irrigation rates that optimize the saturation of soils without interfering with plant growth.
 |
| Soils | * Avoid irrigating high-clay soils with high-salinity stormwater. Salt reduces the permeability of clay soils by increasing the stickiness of clay soils when wet and forming hard clods and crusts upon drying (See http://soiltesting.tamu.edu/publications/E-60.pdf)
 | * Regular monitoring of stormwater runoff and soil quality if salt contamination of soils is a concern
 |
| Aquatic ecosystems | * Avoid [inventoried public waters and wetlands](http://www.dnr.state.mn.us/waters/watermgmt_section/pwi/download_lists.html) for storage of harvested stormwater
* Install aeration systems in storage ponds to minimize algal blooms, if allowed by local code or ordinance
* Pre-storage treatment systems
 | * Regular monitoring of storage pond for adverse ecological impacts
 |
| Local hydrology | * Design storage residence times and overflow volumes such that downstream hydrology is not adversely impacted
 | * Regular inspection and maintenance of storage, overflow and distribution system components
 |
| Equipment degradation | * Source control BMPs
* Pre-storage treatment and treatment systems
 | * Regular inspection and cleaning of system components
 |

# Key Resources

* **Chapter 5-Characterization and mitigating human health and environmental risks** in: The National Academies of Sciences, Engineering, and Medicine (NAS). 2016. [*Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs, and Benefits*](http://www.nap.edu/read/21866/chapter/7). Washington, DC: The National Academies Press.
* United States Environmental Protection Agency. [Risk Assessment Webpage](https://www.epa.gov/risk).
* **Section 2.5-Environmental Considerations** in: United States Environmental Protection Agency (US EPA). September 2012. [Guidelines for Water Reuse](http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf). Document ID EPA/600/R-12/618.
* Natural Resource Management Ministerial Council, Environment Protection and Heritage Council, and National Health and Medical Research Council. 2008. [*Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2) - Stormwater Harvesting and Reuse*](http://www.environment.gov.au/system/files/resources/9e4c2a10-fcee-48ab-a655-c4c045a615d0/files/water-recycling-guidelines-augmentation-drinking-22.pdf).