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| Project Name | | Minnesota Stormwater Manual Harvest and Use Updates | Date | | 7-28-2016 |
| To / Contact info | | Anne Gelbmann | | |
| Cc / Contact info | | Mike Trojan | | |
| From / Contact info | | Meghan Funke, PhD  Paula Kalinosky | | |
| Regarding | | Task F. Water Quality Considerations | | |

# (Includes all tech team members comments: August 9 version)

# Pollutants in harvested water

The composition of stormwater is highly variable in space and time due to differences in land use and rainfall events. This variability is an extremely important consideration when evaluating the feasibility of a stormwater harvesting and use system and determining what level of treatment is necessary to achieve the water quality criteria of the end use.

[Common pollutants in stormwater runoff](http://stormwater.pca.state.mn.us/index.php/Common_pollutants_of_concern_and_sources_in_stormwater_runoff) include nutrients, sediments, heavy metals, salinity, pathogens, and hydrocarbons (Table 1). Water quality of stormwater varies depending on the type of land uses in the drainage area, such as [commercial, industrial, residential and parks/open spaces](http://stormwater.pca.state.mn.us/index.php/Concentrations_of_contaminants_found_in_stormwaterhttp:/stormwater.pca.state.mn.us/index.php/Concentrations_of_contaminants_found_in_stormwater). Typical urban stormwater quality characteristics for the Twin Cities and two other cities are summarized in Table 2.

Table . Typical stormwater pollutants, summary of sources and potential concerns for harvest and use (summarized from [NAS 2016](http://www.nap.edu/catalog/21866/using-graywater-and-stormwater-to-enhance-local-water-supplies-an))

| **Pollutant** | **Sources** | **Potential Concerns** |
| --- | --- | --- |
| Nutrients   * Nitrogen * Phosphorus | * atmospheric deposition, sediment (adsorbed nutrients) * organic debris * fertilizer runoff * animal feces * combined sewer overflows | * Support growth of algae or unwanted microbial growth on the water surface in the storage unit. |
| Organic Matter | * Organic debris (leaves, flowers, pollen, twigs, insect carcasses, etc.) | * Decomposition in tank can result in low dissolved oxygen levels, nuisance odors, and release of pollutants from sediments |
| Suspended Sediment | * paved surfaces * areas of bare soil/poor vegetative cover * construction activity * stockpiles | * May clog pump intake or distribution * Increases maintenance of storage |
| Chlorides | * De-icing chemicals * water softening chemicals | * Corrosive to metal pipes/plumbing * Plant toxicity (irrigation) |
| Pathogens | * animal feces (including bird feces on rooftops) * insects/vector organisms * drainage area activities such as waste management * sewage overflows or leaking sewers | * Human health risk |
| Metals | * Vehicle exhaust * Roofing materials * Drainage area activities that are potential sources of metals (e.g. vehicle fueling or repair) | * Plant toxicity |
| Organic Chemicals   * Pesticides/herbicides * Industrial chemicals and solvents * Petroleum-derived chemicals | * Drainage area activities that are potential sources of organics (e.g. herbicide/ pesticide use or waste management) | * Plant toxicity * Human health risk * Animal health risk |

Table . Typical Annual and Snowmelt Urban Stormwater Quality Characteristics

| **Constituent (concentrations reported in mg/L)** | **Annual** | | | **Twin Cities Snowmelt4** | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Twin Cities1** | **Marquette, MI2** | **Madison, WI3** | **Storm Sewers** | **Open Channels** | **Creeks** | **NURP5** |
| Cadmium | -- | 0.0006 | 0.0004 | -- | -- | -- | -- |
| Copper | -- | 0.022 | 0.016 | -- | -- | -- | -- |
| Lead | 0.060 | 0.049 | 0.032 | 0.16 | 0.2 | 0.08 | 0.18 |
| Zinc | -- | 0.111 | 0.203 | -- | -- | -- | -- |
| Biological Oxygen Demand | -- | 15 | -- | -- | -- | -- | -- |
| Chemical Oxygen Demand | 169 | 66 | -- | 169 | 82 | 84 | 91 |
| Total Kjeldahl Nitrogen | 2.62 | 1.50 | -- | 3.52 | 2.36 | 3.99 | 2.35 |
| Nitrate-Nitrite | 0.53 | 0.37 |  | 1.04 | 0.89 | 0.65 | 0.96 |
| Ammonia | -- | 0.2 | -- | -- | -- | -- | -- |
| Total Phosphorus | 0.58 | 0.29 | 0.66 | 0.7 | 0.56 | 0.54 | 0.46 |
| Dissolved Phosphorus | 0.20 | 0.04 | 0.27 | 0.25 | 0.18 | -- | 0.16 |
| Chloride3 | -- | -- | -- | 230 | 49 | 116 | -- |
| Total Suspended Solids | 184 | 159 | 262 | 148 | 88 | 64 | -- |
| Volatile Suspended Solids | 66 | -- | -- | 46 | 15 | -- | -- |

1 Event mean concentrations; Reference: Brezonik and Stadelmann 2002

2 Geometric mean concentrations; Reference: Steuer et al. 1997

3 Geometric mean concentrations; Reference: Waschbusch et al. 1999

4 Reference: Oberts, G. (Met Council). 2000. Influence of Snowmelt Dynamics on Stormwater Runoff Quality.

5 Reference: Median concentrations from more than 2,300 rainfall events monitored across the nation; EPA, 1983

## Water Quality Considerations of Runoff from Specific Source Areas:

The source area from which stormwater is collected largely determines the water quality characteristics of harvested stormwater (Table 7). Most stormwater is collected from a mix of source areas, however stormwater harvested for use can often be collected from one dominant source area since the catchment area of the systems tend to be smaller than other larger scale stormwater BMPs. This section discusses the unique water quality considerations for stormwater harvest and use systems for the following source areas:

* Hard roofs
* Green and brown roofs
* Paved surfaces
* Green spaces

### Hard Roofs

Table 4 provides a summary of typical roof runoff quality in Minneapolis and Wisconsin. High metal concentrations in rooftop runoff are a major water quality consideration for harvest and use systems (Table 5). Hard rooftops may be composed of a variety of materials (ex. clay/concrete tile, asphalt/composite/wood shingles, metal, slate, or rubberized roofs). Although runoff collected from rooftops is generally high quality compared to other sources of stormwater ([NAS 2016](http://www.nap.edu/catalog/21866/using-graywater-and-stormwater-to-enhance-local-water-supplies-an)), certain roof materials may adversely affect the quality of harvested rainwater (Table 3). Other water quality concerns for rooftops include pathogens which may be found in bird or animal feces and organic litter from tree canopy which may contribute to biological oxygen demand.

Table . Common roofing materials and water quality considerations (Table adapted from ARSCA Rainwater Harvesting Manual, Table 8.2)

| **Roofing Material** | **Water Quality Considerations** |
| --- | --- |
| Metal Roofs | * Runoff may contain high levels of zinc, copper, and lead (see Table 5) |
| Sheet Roofing (PVC) | * Recommended for non-potable use only |
| Tile roofs (clay, ceramic, cement, fiberglass) | * Need periodic cleaning - debris may accumulate between tiles * Recommended for non-potable use only |
| Shingles   * asphalt * composite * three tab asphalt | * Recommended for non-potable use only * Some shingles manufactured prior to 1980 may contain asbestos in trace amounts * May not be suitable for irrigation if shingles have been treated for mold eradication or with herbicides |
| Shingles – cedar shakes/wood shingles | * Recommended for irrigation only * Shingles retain moisture, support mold, algae, and insects, may be treated with fire retardant or other chemicals |

Table . Typical Roof Runoff Quality in Minneapolis and Wisconsin (From Table R.1b.1 in [Met Council 2011](http://www.metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning/Studies-Projects-Workgroups-(1)/Completed-Studies-Projects/Stormwater-Reuse-Guide.aspx))

| **Constituent** | **Minneapolis1** | **Wisconsin2** |
| --- | --- | --- |
| *E. coli* (#/100 mL) | 764 |  |
| Total Solids (mg/L) | -- | 126 |
| Suspended Solids (mg/L) | 10 | 19 |
| Total Hardness (mg/L) |  | 44 |
| Total Nitrogen (mg/L) | 0.421 |  |
| Ammonia-N (mg/L) | 0.268 |  |
| Nitrate-N (mg/L) | 0.586 |  |
| Total Phosphorus (mg/L) | 0.104 | 0.24 |
| Total Dissolved Phosphorus (mg/L) | 0.076 | 0.11 |
| Soluble Reactive Phosphorus (mg/L) | 0.065 |  |
| Cadmium (mg/L) |  | 0.0004 |
| Copper (mg/L) | 0.0075 | 0.01 |
| Lead (mg/L) | 0.0032 | 0.01 |
| Zinc (mg/L) | 0.101 | 0.363 |

1 Arithmetic mean concentrations; Reference: Minneapolis Public Works, City of Minneapolis Neighborhood Rain Barrel Partnership Project, 2008

2 Highest geometric mean concentration reported; Reference: Roger T. Bannerman and Richard Dodds, Sources of Pollutants in Wisconsin Stormwater, 1992

Table . Concentrations of Zinc, Copper, and Lead in Roof Runoff Based on Roof Material Type (From Table 4-1-1 in [NAS 2016](http://www.nap.edu/catalog/21866/using-graywater-and-stormwater-to-enhance-local-water-supplies-an))

|  |  |  |
| --- | --- | --- |
| **Metal** | **Roof Materials** | **Runoff Concentration (mg/L)** |
| Zinc | New uncoated galvanized steel | 0.5-10 |
| Old uncoated galvanized steel | 1-38 |
| Coated galvanized steel | 0.2-1 |
| Uncoated galvanized aluminum | 0.2-15 |
| Coated galvanized aluminum | 0.1-0.2 |
| Other (aluminum, stainless steel, titanium, polyester, gravel) | <0.002 |
| Copper | Uncoated copper | 0.002-0.175 |
| Uncoated galvanized steel | <0.003 |
| Clay tiles | 0.003-4 |
| New asphalt shingles | 0.01-0.2 |
| New cedar shakes | 1.5-27 |
| Aged/patinated copper | 0.9-9.7 |
| Lead | Uncoated galvanized steel | 0.001-2 |
| Coated and uncoated galvanized steel | <0.0001-0.006 |
| Painted materials | <0.002-0.6 |

Zinc data: Clark et al. (2008a,b); Faller and Reiss (2005); Förster (1999); Gromaire-Mertz et al. (1999); Heijerick et al. (2002); Mendez et al. (2011); Schriewer et al. (2008); Tobiason (2004); Tobiason and Logan (2000); Zobrist et al. (2000).

Copper data: Clark et al. (2008a); Gromaire-Mertz et al. (1999); Karlen et al. (2002); Wallinder et al. (2009); Zobrist et al. (2000).

Lead data: Clark et al. (2007); Davis and Burns (1999);Förster (1999); Gromaire-Mertz et al. (1999); Good (1993); Gumbs and Dierberg (1985); Mendez et al. (2011); Shriewer et al. (2008).

### Green and Brown Roofs

Filtrate from green and brown roofs may require little or no treatment since green and brown roofs are effective at removing sediment, although soluble nutrient concentrations (nitrogen and phosphorus) may be elevated and water may be colored.

### Paved Surfaces

Paved surface source areas include parking lots, sidewalks, driveways, and roadways. Table 6 provides a summary of water quality characteristics for several types of paved surfaces. Runoff from paved surfaces can contain higher levels of chlorides, solids, and hydrocarbons. Harvest and use systems collecting runoff from paved surfaces will likely require some sort of first flush diverter to bypass very high concentrations of pollutants in spring snowmelt, and potential toxic spills in the drainage area, Treatment may also require filtration units capable of removing fine solids and hydrocarbons.

Table . Urban Stormwater Quality Characteristics from Paved Surfaces (Adapted from Table R.1b.3 in [Met Council 2011](http://www.metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning/Studies-Projects-Workgroups-(1)/Completed-Studies-Projects/Stormwater-Reuse-Guide.aspx))

| **Constituent (concentrations reported in mg/L)** | **Wisconsin Data1** | | | | | **Twin Cities Highways2** |
| --- | --- | --- | --- | --- | --- | --- |
| **Arterial Street** | **Feeder Street** | **Collector Street** | **Parking Lot** | **Residential Driveway** |
| Cadmium | 0.0028 | 0.0008 | 0.0017 | 0.0012 | 0.0005 | 0.0025 |
| Chromium | 0.026 | 0.007 | 0.013 | 0.016 | 0.002 | -- |
| Copper | 0.085 | 0.025 | 0.061 | 0.047 | 0.02 | 0.023 |
| Lead | 0.085 | 0.038 | 0.062 | 0.062 | 0.02 | 0.242 |
| Zinc | 0.629 | 0.245 | 0.357 | 0.361 | 0.113 | 0.123 |
| Nitrate-Nitrite | -- | -- | -- | -- | -- | 0.77 |
| Total Phosphorus | 1.01 | 1.77 | 1.22 | 0.48 | 1.5 | 0.43 |
| Total Dissolved Phosphorus | 0.62 | 0.55 | 0.36 | 0.07 | 0.87 | -- |
| Chloride3 | -- | -- | -- | -- | -- | 11.5 |
| Total Suspended Solids | 993 | 1152 | 544 | 603 | 328 | -- |
| Suspended Solids | 875 | 1085 | 386 | 474 | 193 | -- |
| Total Dissolved Solids | -- | -- | -- | -- | -- | 157.3 |
| Total Hardness | 41 | 30 | 32 | 48 | 34 | -- |

1 Arithmetic mean concentration; Reference: Roger T. Bannerman and Richard Dodds, Sources of Pollutants in Wisconsin Stormwater, 1992

2 Reference: University of Minnesota Water Resources Center, Assessment of Stormwater Best Management Practices Manual, 2008

3 Data represents chloride concentrations during monitoring season, typically April through October. Chloride concentrations in winter snowmelt grab samples have been found to be as great as 3,600 mg/L.

### Green Spaces

Green space source areas include lawns and park areas (see ‘Open Space’ land use in the [Concentrations of contaminants found in stormwater](http://stormwater.pca.state.mn.us/index.php/Concentrations_of_contaminants_found_in_stormwater) table). Green spaces typically have lower concentrations of pollutants compared to stormwater source areas. Due to the presence of pets and/or wildlife (particularly Canadian geese), these areas may have very high concentrations of pathogens and require disinfection treatment for certain end uses.

Table . Summary of pollutants typically found in stormwater by source area.

| **Source Area** | **Solids** | **Total Suspended Solids** | **Particulate Nutrients** | **Dissolved Nutrients** | **Bacteria** | **Metals** | **Chlorides** | **Grease, Oil** | **Pesticides** | **Other Chemicals** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Hard Roofs |  |  | ⭘ | ⭘ | ⭘ | ⚫ |  |  |  | ⭘ |
| Green and Brown Roofs |  | ⭘ | ⭘ | ⚫ | ⭘ | ⭘ |  |  |  | ⭘ |
| Paved Surfaces | ⭘ | ⚫ | ⭘ | ⭘ |  | ⭘ | ⚫ | ⚫ |  | ⭘ |
| Green Spaces | ⭘ | ⚫ | ⚫ | ⚫ | ⚫ |  |  |  | ⚫ | ⭘ |
| Sedimentation Basins and Detention Ponds | ⭘ | ⭘ | ⭘ | ⚫ | ⭘ | ⭘ | ⭘ | ⭘ |  |  |

⚫ = relatively high concentrations; ⭘ = relatively low concentrations

## Seasonal Considerations

In addition to variability in stormwater quality from different source areas, stormwater quality also varies with season. Table 2 illustrates water quality characteristics of snowmelt in the Twin Cities Metropolitan Area. Seasonal considerations include the following.

* Snowmelt can have very high concentrations of chlorides and sediment from winter road de-icing practices (see Table 2).
* In spring, organic litter including pollen may increase BOD and residual solids on pavement may increase TSS.
* In fall, leaf litter may contribute to BOD, nutrients and solids.

# Treatment Requirements

Water quality criteria have been developed for stormwater harvest and use systems in many states and are summarized in Toolbox R.3b of the 2011 Met Council Stormwater Reuse Guide. The only existing criteria in the State of Minnesota are for stormwater harvest and use systems regulated by Chapter 17 of the Plumbing Code (see below). The National Water Research Institute is currently sponsoring an Independent Advisory Panel to develop national risk-based treatment requirements for stormwater harvest and use systems (see below). Treatment requirements will be based on risk of exposure to harvested stormwater instead of based on achieving end-use water quality criteria. For each level of risk, certain levels of treatment and risk barriers will be required. A risk-based approach for stormwater harvest and use treatment is more appropriate than end use-based water quality criteria due to the wide range of harvested stormwater quality, pathways for exposure, and project specific circumstances.. Please check this page for the most up-to-date treatment requirements during the design of each stormwater harvest and use system project. Post-storage treatment processes available to reduce risk of exposure are described below.

Table . Risk-based treatment requirements for stormwater harvest and use systems

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Risk Level | Description | Site Barriers | Filtration | Disinfection | Other treatment barriers |
| Low exposure | No direct physical contact | None |  |  |  |
| Medium exposure | Direct physical contact | Signage |  |  |  |
| High exposure | Ingestion or inhalation | Restricted access |  |  |  |

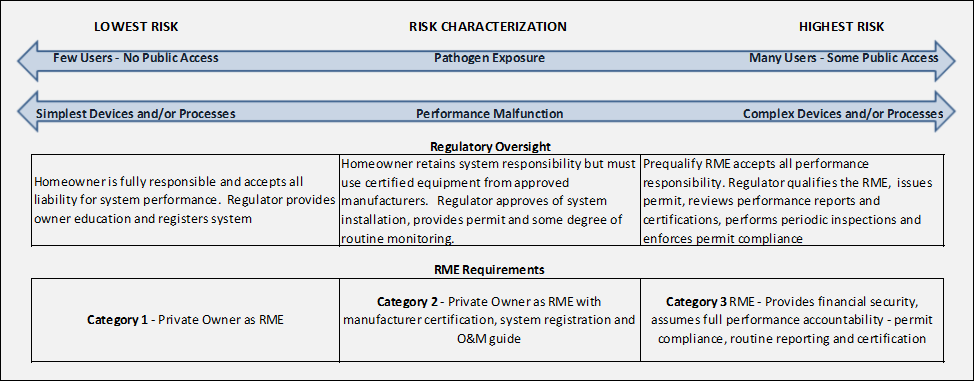
## NWRI Independent Advisory Panel Findings

The primary public health concern with stormwater reuse systems is pathogenic microorganisms. Traditionally, water and wastewater systems have been monitored using fecal indicator organisms (FIO) such as E. coli. The presence or concentration of FIO in a water or wastewater samples was assumed to be indicative of other waterborne pathogens. The FIO were useful because they were expected to be present in water contaminated with fecal waste. However, there are a number of limitations with the use of FIO including (a) FIO may not always be present in stormwater, (b) FIO are not necessarily representative of other pathogen groups, (c) grab samples analyzed for FIO cannot be used for continuous monitoring, and (d) FIO are more difficult to measure consistently than other surrogate parameters. Therefore, state agencies are currently working on procedures for designing and monitoring stormwater reuse systems in more effective ways.

Water quality monitoring and control systems are used commonly to assess the operation, performance, and status of a given component or process. The fundamental purpose of performance target monitoring of a stormwater reuse system is to ensure that the treatment barriers that have been put in place to meet the specified water quality targets are operating as intended.

Most non-potable water systems utilize a number of unit processes in series to accomplish treatment, known commonly as the multiple barrier approach. Multiple barriers are used to improve the reliability of a treatment approach through process redundancy, robustness, and resiliency.

When multiple treatment barriers are used to achieve pathogen removal, the contribution from each barrier is cumulative. In addition to these treatment barriers, operational and management barriers are used to ensure that the systems are in place to respond to non-routine operation. The technical barriers can be monitored using operational and critical control points.



## Minnesota Plumbing Code

The new 2015 Minnesota Plumbing Code, Minnesota Rules, Chapter 4714, took effect **Jan. 23, 2016**. The code now includes the design and installation of harvesting rainwater from building roof tops in Chapter 17, Nonpotable Rainwater Catchment Systems. Nonpotable rainwater catchment systems are acceptable for use to supply water to water closets, urinals, trap primers for floor drains, industrial processes, water features, vehicle washing facilities, and cooling tower makeup water provided the design, treatment, minimum water quality standards, and operational requirements are in accordance with Chapter 17 of the code. Designs must be approved by a Minnesota registered professional engineer.

Rainwater catchment systems use for plumbing applications listed above in combination with lawn irrigation must meet the requirements of Chapter 17.  System components used solely for lawn irrigation, such as irrigation pumps and piping mounted outside of buildings are not subject to the requirements of Chapter 17.   *The conveyance of the rainwater catchment system is still governed by the plumbing code.*

Minimum water quality standards are now described in Chapter 17.

“1702.9.4 Minimum Water Quality. The minimum water quality for rainwater catchment systems shall meet the applicable water quality recommendations in Table 1702.9.4”

|  |  |
| --- | --- |
| **Measure** | **Limit** |
| Turbidity (NTU) | <1 |
| E. coli (MPN/100 mL) | 2.2 |
| Odor | Non-offensive |
| Temperature (degrees Celsius) | MR |
| Color | MR |
| pH | MR |

MR-measure and record only; Treatment: 5 micron or smaller absolute filter; Minimum .5-log inactivation of viruses.

## Treatment systems

Stormwater harvest and use systems require some level of pre-treatment, similar to other stormwater BMPs, such as:

* source control
* debris/coarse solids removal, and
* suspended solids removal.

These pre-treatment processes are not discussed here. Additional post-storage treatment requirements for stormwater harvest and use systems defined in Table 8, including:

* dissolved solids removal,
* disinfection, and
* other additional treatments (such as chlorine residual removal and pH adjustments),

are summarized in Table 9.

Table . Post-Storage Treatment Process Considerations Table (Adapted from Table R.4a in [Met Council 2011](http://www.metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning/Studies-Projects-Workgroups-(1)/Completed-Studies-Projects/Stormwater-Reuse-Guide.aspxhttp:/www.metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning/Studies-Projects-Workgroups-(1)/Completed-Studies-Projects/Stormwater-Reuse-Guide.aspx) and Table 6-7 in [NAS 2016](http://www.nap.edu/catalog/21866/using-graywater-and-stormwater-to-enhance-local-water-supplies-an))

| **Post-Storage Treatment Process** | **Description and Considerations** | **Treatment Alternatives** | **Target Pollutants** | **Capital Cost** | **O&M Level** | **Energy Needs** | **Advantages over Alternatives** | **Disadvantages over Alternatives** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Dissolved Solids Removal | Filtration generally is used to remove residual solids that will not settle spontaneously from harvested water through sedimentation or which may become re-suspended in storage. Filters come in a variety of different types and sizes. The type of filter depends on the class of pollutants targeted for removal. | Coarse & fine filters | * Suspended solids | Med | Med | Med | * Lower overall O&M costs than other filtration | * Does not remove micro-organisms |
| Micro-filtration | * Suspended solids * Micro-organisms | Med | Med | Med | * Smaller footprint required * May reduce disinfection requirements * Captures microorganisms | * Higher capital costs * Higher O&M costs including membrane replacement, energy, performance monitoring, and residuals disposal |
| Nano-filtration | * Dissolved salts * Bacteria/ viruses * Proteins | Med | Med | High | * Requires less energy than reverse-osmosis and ion-exchange filters | * Requires large amount of pretreatment to remove metals that cause scaling and particulates that cause biofouling * Produces a larger waste stream than reverse-osmosis |
| Reverse-osmosis | * Dissolved salts * Dissolved solids * Ions * Bacteria/ viruses | High | High | High | * Highest removal efficiency * Produces the smallest waste stream * Commercially available | * Requires more energy than nanofiltratoin |
| Ion-exchange filter | * Charged ions * Dissolved salts | High | High | High | * Requires the least amount of pretreatment | * Produces the largest waste stream * Requires more energy than nanofiltration * Make-up water is required to continuously wash membranes |
| Disinfection | Disinfection processes kill, remove, or deactivate pathogenic microorganisms in harvested water. | Chlorination – injects chlorine into stormwater | * bacteria * viruses * other pathogenic organisms | Low | Low | Low | * Most common disinfection technology * Least cost | * Requires calibration of dosage control devices * Does not kill cysts |
| Ultra-violet light (UV) radiation – stormwater is passed over an ultraviolet lamp | Med | High | High | * No byproducts * Minimal energy requirements compared to chlorination/ozonation | * Requires cartridge filters ahead of the UV light, with routine cleaning of filters – UV is ineffective on unfiltered stormwater * UV lamps must be replaced periodically |
| Ozonation – diffused ozone released through a fine bubble diffuser at the bottom of the storage tank (possible with stormwater but rarely used) | Med | Med | Med | * Also removes dissolved organics * More effective disinfectant than chlorination | * Treatment of off-gases required * High energy requirements * Corrosion protection required * Requires monitoring of influent to adjust doses * Requires routine check for leaks |
| Other treatments (e.g., pH adjustment) | Treatment for pH adjustment may be needed if the end use of harvested water requires a neutral pH or if harvested water will come in contact with metal pipes or surfaces. Rainwater tends to be slightly acidic and harvested stormwater may retain this characteristic. Acidity can cause metal pipes to corrode leading to contamination of harvested water. | Chemical additive | * acidic or alkali substances | Low | Low | Low | * N/A | * N/A |