



# **Rain Barrel Water Reuse: Summary of Research and Recommendations**

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# Rain Barrel Water Quality and Safe Use

## *Introduction*

Many residential stormwater technical assistance programs recommend the use of rain barrels to capture and reuse water flowing off rooftops during storm events (Akaogi et al., 2010). A rain barrel is a storage container, typically sized around 50-200 gallons, used to hold rooftop runoff for reuse. Cisterns are much larger systems and can hold thousands of gallons of runoff. In a one-inch rainstorm, a typical rooftop area of 1,000 square feet can produce 600 gallons of water per inch of rainfall (Kloss, 2008). Without any stormwater management techniques in place, this water can flow off residential properties, discharge to a water body, and contribute to higher stream flows and pollution transport to receiving water bodies.

Installing rain barrels or cisterns to collect precipitation that falls on rooftops is one option to minimize the amount of water that may otherwise flow to a local waterway following a storm event. These techniques can be an appealing option to collect and store water that can be used on garden plants between storms, minimizing use of tap water. As such, rain barrels are promoted as a water conservation practice and can increase resilience of property owners to drought. Alongside these benefits of rain barrels, there are concerns about the safety and potential contamination risk of using rainwater to sustain moisture needs of garden plants after that water encounters various rooftop materials. Technical service providers in Vermont are interested in promoting science-based recommendations to the public, so that people who choose to use rain barrels know the benefits and potential risks.

Lake Champlain Sea Grant developed this white paper to help property owners and renters understand the issues and be able to make informed decisions about when and how water collected through such systems can be most safely used. Below we provide a summary of major themes we identified across peer-reviewed primary literature that addressed this topic. We also reviewed recommendations from fact sheets developed by Cooperative Extension programs based at universities across the country and other similar entities. Finally, a summary and key findings are provided for each publication reviewed.

## Summary of Major Themes

### *Non-Potable Use Only*

Across the peer-reviewed literature and Cooperative Extension resources we reviewed, a clear consensus emerged that rainwater collected from rain barrels should only be used for non-potable purposes (Hamilton et al., 2019; Hamilton et al., 2018; Shuster et al., 2013).

Publications from researchers and Cooperative Extension programs from the University of Connecticut, Pennsylvania State University, Rutgers University, and the University of Arkansas all emphasized that harvested rainwater is unsafe for drinking, cooking, or washing due to frequent microbial and metal contamination due to its exposure to rooftops during the collection process (Hamilton et al., 2018; Shuster et al., 2013). Common contaminants identified in rainwater collected through such systems included *E. coli*, coliform bacteria, and heavy metals like zinc and lead (Hamilton et al., 2018; Degenhart & Helmreich, 2022). These often originated from animal droppings on roofs and leaching of chemicals from roofing materials such as asphalt shingles and metal surfaces. While collected rainwater can be used for ornamental irrigation, watering lawns, or washing tools, edible crops should only be watered at the soil level. To reduce exposure to potentially dangerous chemicals and bacteria, harvested rainwater should not be directly applied to vegetation. Good hygiene practices such as washing hands after gardening and rinsing harvested produce can further reduce exposure risks.

### *Pollutants of Concern*

Over the past two decades studies have analyzed water samples collected from rain barrel water harvesting systems for common pollutants. Over half of tested rain barrels in Ohio and Philadelphia contained fecal bacteria or pathogens such as *Legionella* and *Mycobacterium*, exceeding EPA standards for potable use (Shuster et al., 2013, Hamilton et al., 2018). In addition to microbial contamination, elevated levels of lead and zinc were observed in some stored rainwater samples, demonstrating that chemical pollutants can accumulate within rain barrels over time (Hamilton et al., 2018). Recently, roof-harvested stormwater was observed to contain both inorganic and organic contaminants, with polycyclic aromatic hydrocarbons (PAHs) consistently detected in runoff (Lay et al., 2024). PAH concentrations were highest in the initial runoff as accumulated atmospheric pollutants were washed off at the start of rainfall. Although levels remained well below health-based thresholds, repeated wash off led to measurable PAH accumulation in soils beneath downspouts, indicating a diffuse long term pollutant source if left untreated.

### *Rooftop Material*

The safety and quality of harvested rainwater are influenced by roof material and maintenance. Metal and concrete tile roofs generally yielded cleaner runoff, while shingle or green roofs were more prone to organic and bacterial contamination (Mendez et al., 2010). Global reviews reinforced that no roof type or system is completely free of risk, and even green roofs may release nutrients or metals requiring treatment prior to use (Hamilton et al., 2019, Degenhart & Helmrich 2022). In fact, all roof materials, whether metal, shingle, clay tile, or gravel, can contribute some level of contaminant wash off, including trace organic pollutants such as PAHs,

indicating that rooftop material consistently shapes the baseline quality of harvested stormwater (Lay et al., 2024).

### *Best Management Practices and Maintenance*

Best management practices for rainwater harvesting include first-flush diversion (Morgado et al., 2022), mesh screening, and routine barrel cleaning (Shuster et al., 2013) targeting different pathways of contamination. First flush devices specifically address pollutants mobilized at the onset of rainfall which is important as the earliest runoff contains the highest concentrations of PAHs and other deposited contaminants (Lay et al., 2024). In Maryland, a first flush rainwater harvesting and subsurface irrigation system in vegetable gardens met microbial food safety standards, with only minor increases following rainfall or in wetter soils (Morgado et al., 2022). Further, when first flush diversion, seasonal maintenance, and appropriate irrigation timing were used, non-potable uses such as garden irrigation were reliably supported (Moore et al. 2023, Vidal et al., 2024).

Other best management practices that can be employed during rainwater harvest include periodic disinfection, clear labeling of rainwater outlets and containers as non-potable (not for drinking), and overflow systems routed to permeable surfaces (Lay et al. 2024). These practices help to mitigate risks associated with internal sediment accumulation, microbial growth, and user exposure to rooftop contaminants. (Lay et al. 2024). Regular turnover of stored water and removal of accumulated sediment within rain barrels or cisterns helps prevent stagnation and contaminant buildup (Shuster et al., 2013). Routing overflow or draining barrels to non-portable garden areas can also help reduce localized soil saturation and pollutant accumulation near storage areas (Lay et al., 2024).

### *Summary of Fact Sheets*

State and Federal Cooperative Extension publications often translated research findings into guidance for a public audience. Fact sheets from programs including the University of Connecticut Extension, Pennsylvania State University Extension, and North Carolina State University Extension emphasize that rain barrels are effective tools for water conservation and stormwater reduction but are not intended for potable use. Rather than reiterating laboratory findings, these resources focused on public safety messages and recommended maintenance practices for rain barrel systems. These practices included encouraging soil level irrigation rather than direct watering onto plants, installation of first flush diverters, use of mesh screening at the inlet to block debris and insects (Moore et al., 2023) and routine cleaning of roofs, gutters, and barrels/cisterns.

Recent publications including Moore et al. (2023) and guidance from the U.S. Environmental Protection Agency (EPA, 2022), indicate that when systems are properly maintained, harvested

rainwater can safely support non-potable uses such as garden or landscape irrigation. Additional recommendations from the Virginia Cooperative Extension (2020) and Connecticut Department of Energy and Environmental Protection (2009) connect these homeowner practices to wider stormwater management and public health goals, emphasizing importance of proper overflow routing, seasonal maintenance, and community education to ensure safe and sustainable rainwater harvesting.

## Primary Literature Summaries

- I. Degenhart, J., & Helmreich, B. (2022). Review on inorganic pollutants in stormwater runoff of non-metal roofs. *Frontiers in Environmental Chemistry*, 3. <https://doi.org/10.3389/fenvc.2022.884021>

This review analyzed 42 studies on stormwater runoff from nine non-metal roofing materials to assess contamination potential. All roof types released nutrients and heavy metals, with phosphate, copper, lead, and zinc frequently exceeding groundwater protection limits. Some materials, like gravel roofs, retained certain pollutants, while treated wood and metal-guttered roofs released more metals. Overall, runoff from all roofing types was identified as a diffuse pollution source requiring treatment before environmental discharge.

### Key findings:

- o All roof types released inorganic pollutants, with no universally “clean” option; all gravel roofs trapped some contaminants, while treated wood and gutter materials added heavy metals.
  - o Runoff quality depended on rooftop material and maintenance of the rainwater harvesting system; even rainwater harvested from green roofs may need treatment before use to ensure water safety.
- II. Hamilton, K. A., Parrish, K., Ahmed, W., & Haas, C. N. (2018). *Assessment of water quality in roof-harvested rainwater barrels in Greater Philadelphia*. *Water*, 10(2), 92. <https://doi.org/10.3390/w10020092>

The study surveyed 38 small scale rainwater barrels during winter and summer sampling campaigns to evaluate microbial and metal contamination risks. The authors found fecal indicator bacteria in over 60% of samples with counts in some cases exceeding irrigation water standards, indicating microbial concern. Using qPCR, they also detected several opportunistic pathogens, including *Legionella spp.*, and *Mycobacterium intracellulare*, though the pathogenic bacteria *Campylobacter jejuni* (common cause of food poisoning)

were rare or absent. Metals, specifically lead and zinc, were frequently detectable but generally within acceptable limits for non-potable use, except for one zinc outlier. The study concluded that while metal risk appears low under garden use conditions, microbial hazards, especially from aerosolization or contact during gardening, require further attention and may demand treatment, system design improvements, or education for safe usage.

Key findings:

- o Researchers sampled residential rain barrels in Philadelphia to evaluate microbial and metal contamination.
- o Over 60% of samples contained fecal indicator bacteria; opportunistic pathogens, most commonly *Legionella spp.* and *Mycobacterium Intracellulare*, were also detected, and lead and zinc were present in water from most barrels. Findings indicated harvested rainwater should be limited to non-potable uses or treated before use on edible plants.

- III. Hamilton, K., Reyneke, B., Waso, M., Clements, T., Ndlovu, T., Khan, W., DiGiovanni, K., Rakestraw, E., Montalto, F., Haas, C. N., & Ahmed, W. (2019). A global review of the microbiological quality and potential health risks associated with roof-harvested rainwater tanks. *Npj Clean Water*, 2, 7. <https://doi.org/10.1038/s41545-019-0030-5>

The authors reviewed global studies on the microbiological quality and health risks of roof harvested rainwater. They found that fecal indicator bacteria and opportunistic pathogens such as *Legionella* and *Mycobacterium* were common, sometimes at levels above safety guidelines. Although reported illness rates were generally low, risk models showed that untreated rainwater can pose health concerns, particularly vulnerable groups through inhalation or ingestion. The authors concluded that safe reuse depends on proper treatment, system design features like first flush diverters, and regular maintenance.

Key findings:

- o Researchers conducted a global review of studies on the microbiological quality of roof harvested rainwater.
- o Most tanks contained fecal indicator bacteria and occasionally pathogens like *Salmonella* and *Campylobacter*, indicating widespread contamination risk.
- o Findings highlighted the need for household-level treatment and safe-use guidelines before consuming or irrigating with harvested rainwater.

- IV. Lay, J. J., Vogel, J. R., Belden, J. B., Brown, G. O., & Storm, D. E. (2024). *Water Quality and the First-Flush Effect in Roof-Based Rainwater Harvesting, Part I: Water Quality and Soil Accumulation*. *Water*, 16(10), 1402. <https://doi.org/10.3390/w16101402>

This study assessed runoff from 19 small scale and 3 commercial roofs representing asphalt shingle, metal, clay tile, and tar and gravel systems under both simulated and natural rainfall. Researchers tested for 17 PAHs, two phosphorus flame retardants, pyrethroid insecticides, dissolved metals, turbidity, and bacteria. PAHs were routinely detected, especially naphthalene, though concentrations were far below health benchmarks. Roofing materials influenced certain inorganic pollutants, but atmospheric deposition was the primary source of organic contaminants. A strong first flush pollution spike was documented across roof types. Soils beneath downspouts showed long term PAH accumulation, sometimes above EPA residential screening levels. While most water quality measurements fell within EPA's non-potable reuse guidelines, the study concluded that first flush diversion or treatment is necessary.

Key findings:

- o Roof runoff from all materials contained trace PAHs and other contaminants largely from atmospheric deposition.
- o The first flush carried the highest concentration of PAHs, turbidity, conductivity, and suspended solids.
- o Downspout soils accumulated PAHs over time, with some levels exceeding human health screening thresholds
- o Most runoff met EPA non-potable reuse guidelines, but treatment or first flush diversion is needed to reduce contaminant loads.

- V. Mendez, C. B., Afshar, B. R., Kinney, K., Barrett, M. E., Kirisits, M. J., & Texas Water Development Board. (2010). *Effect of roof material on water quality for rainwater harvesting systems*. Texas Water Development Board. <https://greywateraction.org/wp-content/uploads/2014/11/Effect-of-Roof-Material-on-Water-Quality-for-Rainwater-Harvesting-Systems.pdf>

This study investigated how different roof materials influence the quality of harvested rainwater, comparing runoff from metal, shingle, tile, and green roofs under controlled and field conditions. They found that metal and concrete tile roofs generally yielded the cleanest water with lower bacterial and organic contamination, while single and green roofs produced runoff with higher levels of fecal indicator bacteria, organic carbon, and some leached metals. While there were only three sampling events, the study suggests that roof material influences rainwater safety, and systems using higher risk materials should incorporate treatment or first flush controls before reuse.

Key findings:

- Tested rainwater from various roof materials (i.e., metal, shingle, tile, green) to assess differences in water quality at pilot and residential rooftops in Texas.
- Runoff collected directly from roof surfaces showed that metal and tile roofs produced lower concentrations of bacterial indicators and organic content, whereas shingle and green roofs were associated with higher microbial and organic concentrations. Roof material strongly affected runoff quality, meaning material choice and treatment were key for safe rainwater use.

- VI. Morgado, M. E., Hudson, C. L., Chattopadhyay, S., Ta, K., East, C., Purser, N., Allard, S., Ferrier, M. D., Sapkota, A. R., Sharma, M., & Rosenberg Goldstein, R. (2022). The effect of a first flush rainwater harvesting and subsurface irrigation system on *E. coli* and pathogen concentrations in irrigation water, soil, and produce. *Science of the Total Environment*, 843, 156976. <https://doi.org/10.1016/j.scitotenv.2022.156976>

Researchers evaluated a first flush rainwater harvesting and subsurface irrigation system in two Maryland vegetable gardens to determine its safety for food production. The system effectively reduced bacterial risks, with no *Salmonella*- or *Listeria*-causing bacteria were detected and *E. coli* levels were within accepted food safety limits. Minor increases occurred after rainfall or in wetter soils, suggesting that soil moisture management and timing harvest after dry periods can further enhance safety when using harvested rainwater for irrigation.

Key findings:

- Tested a first flush rainwater harvesting and subsurface irrigation system in two Maryland vegetable gardens to assess microbial safety in water, soil, and produce.
- No *Salmonella* or *Listeria* were detected; *E. coli* levels met food safety guidelines and only 7% of produce tested positive, mainly when soils were wetter or after rain.
- The system safely supports non-potable produce irrigation when harvest timing and soil moisture are managed.

- VII. Shuster, W. D., Lye, D., De La Cruz, A., Rhea, L. K., O'Connell, K., & Kelty, A. (2013). Assessment of Residential Rain Barrel Water Quality and Use in Cincinnati, Ohio. *JAWRA Journal of the American Water Resources Association*, 49(4), 753–765. <https://doi.org/10.1111/jawr.12036>

Researchers tested 174 residential rain barrels in Cincinnati and found that the stored water often contained high levels of bacteria like coliforms and *Enterococcus*, exceeding EPA standards. They linked this contamination to roof debris, fecal matter, and stagnant water in rarely used barrels. Although harmful algal toxins weren't a concern, water

quality varied widely depending on how barrels were used and maintained. The study emphasized that rain barrels are valuable for stormwater control but should only be used for non-potable purposes, with regular cleaning and public education to reduce health risks.

Key findings:

- o Analyzed rainwater collected from residential rain barrels in Cincinnati, Ohio.
- o Sample results yielded poor microbial water quality, with high coliform and *Enterococcus* levels.
- o The study recommended strictly for use of collected rainwater for non-potable purposes.

VIII. Tom, M., Fletcher, T. D., & McCarthy, D. T. (2014). Heavy Metal Contamination of Vegetables Irrigated by Urban Stormwater: A Matter of Time? *PLoS ONE*, 9(11), e112441. <https://doi.org/10.1371/journal.pone.0112441>

Researchers simulated the effects of watering edible plants with stormwater over short- and long-term periods by aging garden soils to represent 0, 5, and 10 years of metal buildup. French beans, kale, and beetroot were irrigated for 11 weeks, revealing that lead posed the greatest risk especially in French bean and beetroot leaves, which often exceeded food safety limits. Although metals increased greatly with time, plant uptake rose more gradually and varied by species, with kale showing the lowest accumulation. The authors concluded that using untreated stormwater for irrigation can be viable if low uptake crops are selected, soils are refreshed or mixed regularly, and the water is treated before use.

Key findings:

- o Authors in Australia simulated metal accumulation over time to assess uptake in edible crops grown in contaminated soils in experimentally designed study plots.
- o Lead (Pb) built up most in French beans and beetroots, often exceeding safety limits and increasing with garden age, while kale showed lower uptake.
- o Findings suggest periodic mixing or replacement of soil to reduce long term metal buildup in edible plants.

IX. Vidal, P., Leiva, A. M., Gómez, G., Salgado, M., & Vidal, G. (2024). Water quality of rainwater harvesting systems and acceptance of their reuse in young users: an Exploratory approach. *Resources*, 13(11), 159. <https://doi.org/10.3390/resources13110159>

Authors in Chile examined both the chemical and social dimensions of rainwater reuse, testing harvested water for key quality parameters and assessing perceptions among

young users. The water showed low nutrient and salt concentrations, minimal contaminants, and suitable for non-potable applications like irrigation. The study emphasizes effective communication and technical performance together to determine the success of rainwater reuse programs.

Key findings:

- o Analyzed water quality from three rainwater harvesting systems and surveyed young users before and after an educational session.
- o The harvested rainwater met standards for agricultural reuse, and information sessions increased user acceptance.
- o Combining technical quality with public education supports wider adoption of rainwater reuse.

## Fact Sheets

Akaogi, M., Lake Champlain Sea Grant, University of Vermont Extension, Vt. Department of Environmental Conservation, & Vt. Agency of Natural Resources. (2010). *Absorb the Storm: Create a rain-friendly yard and neighborhood* [Guide]. Lake Champlain Sea Grant. [https://www.uvm.edu/seagrant/sites/default/files/uploads/publication/absorb\\_the\\_storm\\_68037\\_lakechamplain\\_storm.pdf](https://www.uvm.edu/seagrant/sites/default/files/uploads/publication/absorb_the_storm_68037_lakechamplain_storm.pdf)

- o Encourages homeowners to capture and absorb stormwater on their property using rain-friendly landscaping and tools like rain barrels, to protect local waterways.

Allen, J. (2018). *Can I Water Vegetables with my Rain Barrel Water?* UConn Extension. <https://publications.extension.uconn.edu/2018/05/18/can-i-water-vegetables-with-my-rain-barrel-water/>

- o Advises using rain barrel water only for non-potable purposes and watering soil, not edible plant parts, due to possible microbial contamination.

Connecticut Department of Energy and Environmental Protection Bureau of Water Protection and Land Reuse Planning and Standards Division. (2009). *Rainfall as a Resource*. [https://portal.ct.gov/-/media/DEEP/water/watershed\\_management/wm\\_plans/LID/whatisarainbarrelpdf.pdf?la=en](https://portal.ct.gov/-/media/DEEP/water/watershed_management/wm_plans/LID/whatisarainbarrelpdf.pdf?la=en)

- o Rain barrels capture rooftop runoff to conserve water and reduce stormwater pollution, but they must be properly installed and maintained and are not suited for potable use.

DeBusk, K., Hunt, B., Osmond, D., & Cope, G. (2011). *Water quality of rooftop runoff: Implications for Residential water harvesting Systems | NC State Extension Publications*. NC State Extension Publications. <https://content.ces.ncsu.edu/water-quality-of-rooftop-runoff>

- o Researchers found that rooftop runoff often contains nutrients, heavy metals, and bacteria from roof materials and debris. They recommend using harvested rainwater only for non-potable purposes and incorporating first-flush systems to improve water quality.

Kloss, C. (2008). *Managing Wet Weather with Green Infrastructure: Municipal Handbook (Rainwater Harvesting Policies)*. National Service Center for Environmental Publications (NSCEP). <https://Nepis.EPA.gov>

- o Provides guidance on how rainwater harvesting systems function, outlining design components, performance benefits, maintenance needs and potential municipal applications.

Mansberger, J. (2022). *Rain Barrels: Information and guide*. PennState Extension. <https://extension.psu.edu/rain-barrels-information-and-guide>

- o Rain barrel water should only be used on inedible plants and washing cars, tools, outdoor furniture, or boots. It should never be used on edible plants.

Moore, K., McMillan, M., & Bravo, L. (2023). Rain barrel water quality in Florida. *EDIS*, 2023(5). <https://doi.org/10.32473/edis-ep640-2023>

- o Rain barrels from tile, shingle, and metal roofs in South Florida showed no E. coli and low nutrient levels, indicating safe non-potable use. Results may differ in colder climates.

Neponset Stormwater Partnership, Prato, R., Eagle Creek Watershed Alliance, Technicians for Sustainability (tfssolar.com), & Montana State University Extension. (n.d.). *Semi-Arid Green Infrastructure Toolbox Rainwater harvesting Practices*. [https://www.epa.gov/system/files/documents/2022-04/green-infrastructure-toolbox\\_rainwater-harvesting.pdf](https://www.epa.gov/system/files/documents/2022-04/green-infrastructure-toolbox_rainwater-harvesting.pdf)

- o Rainwater harvesting systems reduce stormwater runoff and potable water use when designed and maintained properly.

Spangler, S. (n.d.). *Safe use of rain barrel water | Is it safe to water produce with rain barrel water?* Safe Use of Rain Barrel Water | Is It Safe to Water Produce With Rain Barrel Water? <https://www.uaex.uada.edu/yard-garden/vegetables/rain-barrel-watering-edible-plants.aspx>

- o Advises that rain barrel water should be used for non-potable purposes and recommends applying it to the soil only, not directly on edible produce, to minimize contamination risks

Sample, D., Fox, L. J., & Hendrix, C. (2020). Best Management Practice Fact Sheet 6: Rainwater harvesting. In *Virginia Cooperative Extension*. [https://www.pubs.ext.vt.edu/content/dam/pubs\\_ext\\_vt\\_edu/426/426-125/BSE-274.pdf](https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/426/426-125/BSE-274.pdf)

- o Rainwater harvesting systems intercept, store and release rooftop runoff for later non-potable use while reducing stormwater volume but require proper design and routine maintenance.

Weisenhorn Julie, & Hultberg, A. (2024). *Rain barrels in the home landscape*. University of Minnesota Extension. <https://extension.umn.edu/water-wisely-start-your-own-backyard/rain-barrels>

- o Emphasizes that rain barrel water is non-potable and should be used only for tasks like lawn or garden irrigation, avoiding direct contact with edible plants to reduce microbial and chemical contamination risks.