



A Guide to Rainwater Harvesting

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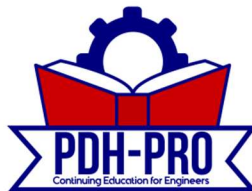
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Module 1: Introduction to Rainwater Harvesting

Learning Objectives

By the end of this module, you will be able to:

- Identify the primary chemical and physical advantages of harvested rainwater compared to municipal or groundwater sources.
- Analyze the environmental and infrastructural benefits of decentralized rainwater catchment systems.
- Evaluate the operational and maintenance responsibilities required for potable and non-potable rainwater harvesting systems.
- Determine the feasibility of integrating rainwater and air-conditioning condensate harvesting across residential, commercial, and industrial applications.

Executive Summary

This module introduces the fundamental concepts, advantages, and applications of rainwater harvesting for professional engineering projects. It outlines the specific water quality benefits, the reduction of infrastructural burdens, and the explicit operational responsibilities assumed by the system owner, providing a baseline for evaluating rainwater catchment as a viable water supply alternative.

Technical Content

Historical Context and Resurgence

Rainwater harvesting is an ancient technique enjoying a revival in popularity due to the inherent quality of rainwater and a growing interest in reducing the consumption of treated water. Archeological evidence demonstrates the capture of rainwater as far back as 4,000 years ago, and the concept of rainwater harvesting in China may date back 6,000 years. Ruins of cisterns built as early as 2000 B.C. for storing hillside runoff for agricultural and domestic purposes are still standing in Israel. Today, modern harvesting systems offer a sustainable, high-quality water source that can close the gap between projected water supply and future demand.

Primary Advantages and Water Quality

Rainwater is highly valued for its purity and softness. It has a nearly neutral pH and is free from disinfection by-products, salts, minerals, and other natural and man-made contaminants. The primary engineering and practical advantages of rainwater harvesting include:

- **Cost of Supply:** The water itself is free; the only associated costs are for the collection and distribution infrastructure.
- **Proximity to Demand:** The end use of the harvested water is located close to the source, eliminating the need for complex and costly distribution systems.
- **Source Alternatives:** Rainwater provides a viable water source when groundwater is unacceptable or unavailable, or it can be utilized to augment limited groundwater supplies.
- **Zero Hardness:** The zero hardness of rainwater helps prevent scale accumulation on appliances, extending their operational life. Furthermore, rainwater eliminates the need for water softeners and the salts added during the softening process.
- **Sodium-Free:** Rainwater is completely sodium-free, which is an important health consideration for persons on low-sodium diets.
- **Plant Health:** Rainwater is superior for landscape irrigation, as plants thrive without the stress of added municipal chemicals or groundwater minerals.
- **Stormwater Management:** Harvesting reduces flow to stormwater drains, lessens the impact on soil erosion, and reduces non-point source pollution. Decreasing stormwater volume keeps potential pollutants, such as pesticides, fertilizers, and petroleum products, out of rivers and groundwater.
- **Utility Relief:** Widespread harvesting helps utilities reduce peak summer demand and delay the costly expansion of existing water treatment plants.
- **Consumer Savings:** Capturing on-site water reduces the consumer's utility bills.

Infrastructural and Health Considerations

A significant aspect of rainwater harvesting is the exclusion of this water demand from the traditional water distribution infrastructure. This bypasses the need for centralized treatment facilities, storage structures, municipal pumps, mains, and laterals. Land-based systems can also incorporate man-made landscape features—such as bermed concave holding areas down a slope—to channel and concentrate rainwater for direct turfgrass or plant irrigation, preventing erosion on sloped surfaces.

When assessing the health risks of drinking rainwater, engineers must consider the path the water takes. In a traditional municipal system, a raindrop travels through a watershed into a reservoir, absorbing contaminants and minerals. While residing in the reservoir, the water can contact oil, animal wastes, chemical and pharmaceutical wastes, organic compounds, industrial outflows, and trash. Centralized treatment plants remove these contaminants and kill pathogens, often using chlorine. However, chlorine degrades into disinfection by-products, notably trihalomethanes, which may pose health risks.



In contrast, a raindrop harvested on-site travels directly down a roof via a gutter to a storage tank. Before it is used for drinking, it is treated by a relatively simple process utilizing equipment that occupies only about 9 cubic feet of space.

Owner Responsibilities and Maintenance

With the independence of a rainwater harvesting system comes the inherent responsibility of operation and maintenance. The owner essentially becomes the operator of their own water supply system.

⚠ Safety Constraint: For all systems, routine maintenance responsibilities include purging the first-flush system, regularly cleaning roof washers and tanks, maintaining pumps, and filtering water.

For potable systems, these responsibilities increase significantly. The owner must:

- Replace cartridge filters on a strict schedule.
- Maintain disinfection equipment.
- Arrange to have water tested regularly (at a minimum, testing for pathogens).
- Monitor tank levels to ensure supply.

System Scale, End-Uses, and Case Examples

Rainwater harvesting systems range from simple rain barrels for urban garden irrigation to complex domestic potable systems or multiple end-use systems at large corporate campuses. Harvesting is practical only when the volume and frequency of rainfall, combined with the size of the catchment surface, can generate sufficient water for the intended purpose.

While the installation and maintenance costs of a residential potable rainwater system generally cannot compete with water supplied by a central utility, it is often cost-competitive with the installation of a new well in rural settings. For commercial and industrial buildings with large catchment surfaces, the captured volume can cost-effectively serve several end uses, such as landscape irrigation and toilet flushing.

Representative Implementations:

- **Municipal/Recreational:** The Wells Branch Municipal Utility District captures rainwater and air-conditioning condensate from a 10,000-square-foot recreation center into a 37,000-gallon tank. This serves as irrigation water for a 12-acre park with soccer fields.
- **Institutional:** The Lady Bird Johnson Wildflower Research Center harvests 300,000 gallons annually from a 19,000-square-foot roof for native plant irrigation, utilizing a distinctive 6,000-gallon stone cistern and aqueduct.
- **Industrial:** The Advanced Micro Devices (AMD) semiconductor fabrication plant does not use utility-supplied water for irrigation, saving \$1.5 million per year by relying entirely

on captured rainwater and collected groundwater. Reynolds Metals utilizes stormwater captured in containment basins as process water in its metal-processing plant.

- **Municipal/Regional Supply:** In locations like Columbia, Nuevo León, Mexico, rainwater is planned as the primary water supply for new industrial growth areas. On small volcanic or coral islands (e.g., Bermuda, the U.S. Virgin Islands) where groundwater is nonexistent or contaminated by saltwater, cisterns are legally required with all new construction.

💡 **Design Tip:** Commercial and industrial buildings can highly optimize their systems by augmenting rainwater with air-conditioning condensate. Warm, moisture-laden air passing over residential cooling coils can produce 10 or more gallons per day, while industrial facilities can produce thousands of gallons daily. A major design advantage of condensate capture is that maximum production occurs during the hottest months of the year, perfectly coinciding with peak irrigation demand. This condensate is typically piped directly into the rainwater cistern for storage.

Checkpoint Quiz

1. Which of the following is a primary chemical advantage of utilizing harvested rainwater for domestic or irrigation purposes?

- a) It contains trace amounts of trihalomethanes for continuous disinfection.
- b) It has a slightly alkaline pH that naturally prevents scale buildup.
- c) It features zero hardness and is completely sodium-free.
- d) It naturally provides essential minerals such as calcium and magnesium to plants.

Answer: (c). Harvested rainwater is highly valued because it is completely sodium-free (beneficial for low-sodium diets) and has zero hardness, which prevents scale accumulation on appliances and eliminates the need for water softeners. It is also nearly neutral in pH, not alkaline.

2. When designing a rainwater harvesting system that incorporates air-conditioning condensate capture, what is the primary operational advantage of this integration?

- a) Condensate provides the necessary chlorine required to disinfect the rainwater storage tank.
- b) Maximum condensate production occurs during the hottest months, perfectly aligning with peak irrigation demands.
- c) Condensate water inherently neutralizes the slight acidity of natural rainfall.
- d) The addition of condensate eliminates the need for a first-flush diverter on the roof catchment.

Answer: (b). The primary advantage of integrating condensate capture is that its peak production occurs during the hot, humid summer months. This directly coincides with the period of highest demand for landscape irrigation, effectively supplementing the water supply when rainfall is typically lowest.



3. If an engineer is specifying a rainwater harvesting system for strictly potable domestic use, which of the following represents a critical operational requirement that the homeowner must adopt?

- a) Applying agricultural fertilizers directly to the cistern to buffer the pH.
- b) Testing the harvested water strictly for trihalomethanes on a weekly basis.
- c) Bypassing the roof washer during high-intensity rainfall events.
- d) Arranging for regular water testing, at a minimum checking for pathogens.

Answer: (d). With a domestic potable system, the owner acts as the operator of their own water supply. They are strictly responsible for maintaining filtration and disinfection equipment, monitoring tank levels, and having the water regularly tested for pathogens to ensure safe drinking standards.



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