Rainwater Harvesting

An Untapped Resource

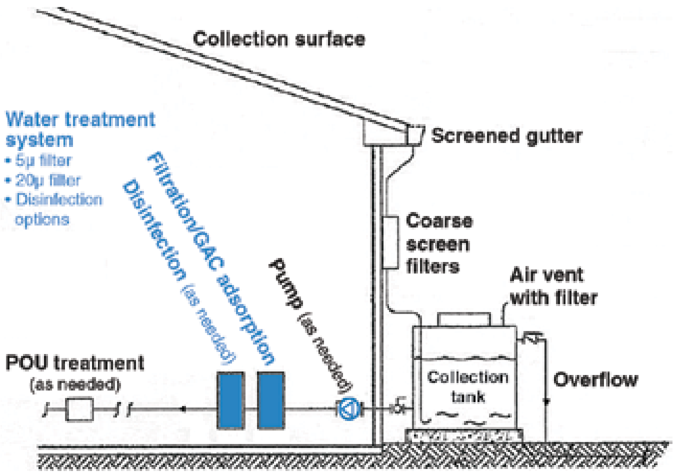
By Peter S. Cartwright, P.E.

The collection of rainwater as a source of relatively clean water has been a common practice of humankind since the dawn of civilization. Before the development of any treatment processes, it was the primary source of potable water for those people without access to other sources of water (rivers, lakes, etc.).

As cities developed, infrastructure became more centralized. Municipalities took over the responsibility of collecting rainwater (stormwater) and generally directing it to the nearest lake or river.

Although household rainwater catchment systems—generally home made, utilizing gutters, downspouts and rain barrels (remember the song?)—were commonly employed to collect water for gardens, those largely faded from the US scene several decades ago. Still rather common in Europe for non-potable applications and widely used in the developing world for all applications, rainwater harvesting is the primary water source available for reclamation and reuse.

Figure 1. Rainwater harvesting



Our air has become increasingly polluted with years of irresponsible behavior by all segments of society and is much dirtier now than when rainwater was collected and consumed thousands of years ago. As rainwater falls to earth, it picks up particle and gaseous contaminants.

Our drinking water quality standards are constantly becoming more stringent. In spite of this, treating rainwater—and stormwater for that matter—requires generally less technology than any other source of wastewater. The reason for this is because rainwater is the purest of virtually all sources of water, is naturally soft and is free of disinfection byproducts.

When used for most non-potable applications (garden watering, landscape irrigation, etc.), it requires little or no treatment. Harvested rainwater costs almost nothing and can significantly reduce dependency on the municipal water provider. As rainwater harvesting becomes more widely used, the decreased stormwater volume will reduce the impact on storm sewers.

Rainwater collection is applicable not only for houses, but for all other buildings and structures—virtually anything with a roof. One inch of rainfall provides 620 gallons (2,346.9 L) of water per 1,000 ft^2 (92.9 m^2) of roof area.

If a rainwater collection system will be used to produce potable quality water, posttreatment is needed (see Figure 1). A note of caution here: depending on the location, legal restrictions may apply regarding the use of such reclaimed water for potable purposes.

Treatment technologies

• ***Filtration.*** This technology is primarily used to remove suspended solids from water supplies. These solids can be dirt, silt or other particulate material. Filtration technologies include:

—**Media filters:** tanks containing granular media such as sand, anthracite, garnet, etc., which capture suspended solids and retain them inside the bed until taken offline and backwashed. Bed filters are typically capable of removing suspended solids down to 10 to20 microns in size (see Figure 2).

—**Cartridge filters:** operating in the same way as bed filters, cartridge filters are replaceable 'inserts' (usually cylindrical in configuration) that are inserted into housings and are typically replaced when they have captured so much suspended solids that the pressure drop across the housing becomes unacceptable (usually above 10 psig). Offered in many different designs and micron removal ratings (down into the submicron range), cartridge filters provide an excellent array of choices to the knowledgeable design engineer (see Figure 3).

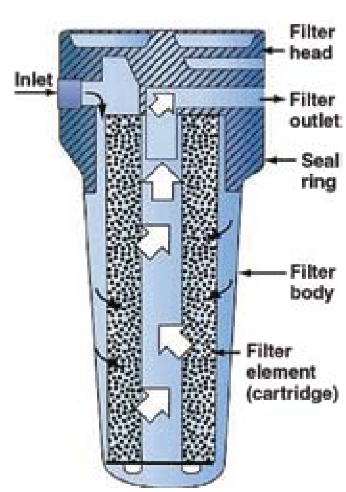
—**Bag filters:** these are similar to cartridge filters except that the medium is fabricated into a bag through which the water flows. Although not available with a micron rating as small as cartridge filters, bag filters are generally 'tighter' than media filters (see Figure 4).

•***Adsorption.*** Adsorption is a phenomenon utilizing the surface energy of a solid adsorbent to attract molecular species from a liquid. The most common adsorbent in water treatment is activated carbon. This product, manufactured from a number of carbon-based materials (coal, coconut shells, wood, peat, etc.) is treated to produce a porous material with very high surface area.

Activated carbon in rainwater harvesting applications is

Figure 2. Media filter

Figure 3. Cartridge filter



used to adsorb dissolved gases and low molecular weight organic compounds (such as VOCs) picked up by rainwater falling through the atmosphere. It is also widely used to remove chlorine from water supplies, although the mechanism of removal, in this case, is actually as a catalyst in an oxidation-reduction reaction (see Figure 5).

This product is available as granules packed into similar housings as used for media filters or as carbon block cartridges. These provide sediment filtration as well as adsorption properties.

• ***Disinfection.*** If the treated water is to be stored or used for culinary purposes, some form of disinfection will be required to inactivate pathogenic microorganisms and keep objectionable bacteria or algae at bay.

• ***Chemical processes.*** The following chemical disinfectants are used in water treatment systems:

—Chlorine. In the US, chlorination of municipal drinking water supplies has been the technology of choice for well over 100 years. Chlorine, with its active ingredient hypochlorous acid, is very effective in inactivating almost all waterborne pathogens. It provides an acceptable residual, but it does have limitations, particularly the formation of dangerous trihalomethane compounds (THMs) in the presence of certain organic compounds.

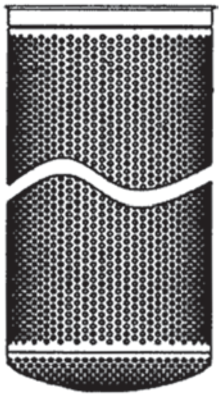
Chlorine is normally pumped into the system as a solution of sodium hypochlorite, fed as tablets of calcium hypochlorite or induced as a gas. It is effective at a residential concentration of one to two ppm. Dissolved chlorine is readily removed by activated carbon adsorption and can be monitored with simple test kits. It is relatively easily rinsed out of the system.

—Monochloramine. This compound, resulting from the reaction of ammonia with chlorine in water, is commonly used in municipal water supply systems because of the superior stability of chloramine compounds over chlorine. A further advantage is that chloramine compounds do not form trihalomethanes; however, monochloramine is not as strong an oxidant as chlorine and thus has less ability to kill bacteria. Concentrations of these compounds in the range of five to 10 ppm are required for effective disinfection.

The industry commonly calls the purposeful formation of monochloramine, simply chloramine; however, most municipalities and homeowners strive very hard not to form dichloramine and trichloramine by ensuring the proper ratio of ammonia to chlorine. Di- and trichloramine provide little disinfection capability and are largely responsible for chlorine smell and eye irritation complaints.

—Chlorine dioxide. Chlorine dioxide exhibits stronger disinfecting characteristics than chloramines, but as it is more expensive than chlorine it is not widely used. Chlorine dioxide does not form THMs and exhibits rinsing, corrosion and handling characteristics similar to those of chlorine. It has to be generated on site. Chlorine dioxide can form chlorite, however, a regulated disinfection byproduct. Recommended concentrations are two to five ppm.

Figure 4. Bag filter



—Iodine. This common relative of chlorine has been used for years by campers and the military for disinfecting drinking water of unknown quality. Unfortunately, certain gram-negative bacteria strains can become resistant to iodine. Much less reactive to dissolved organics than chlorine, it will not form trihalomethanes. The recommended concentration is 0.3 to 0.5 ppm.

All of the above chemicals can be removed from water supplies by activated carbon. It should be noted, however, that not only will the water leaving the activated carbon no longer be disinfected, but the carbon bed itself is an excellent medium for growing bacteria.

—Ozone. This powerful chemical, which consists of oxygen in a three-atom form, is used to disinfect some municipal water supply systems, particularly in Europe. It is very effective; however, it must be generated on site and has a relatively short life (less than 30 minutes), thereby leaving no residual. When used at the recommended concentration of two to three ppm, ozone will kill bacteria, viruses, spores and cysts. Both ultraviolet irradiation and activated carbon will remove ozone from water. The only effective ozone generation technology currently available for disinfection applications is corona discharge.

Care must be taken in handling any of the above chemicals. Their effect on the materials of construction of the water treatment system must be evaluated.

• ***Non-chemical processes***

—Ultraviolet irradiation. Ultraviolet (UV) irradiation is a common method of treating relatively small-scale water supplies. In this process, the water is exposed to ultraviolet radiation after it has been filtered. UV is also effective in inactivating *Cryptosporidium* oocysts.

Only momentary exposure is required to kill microorganisms, but this condition may not be met if the lamps are shielded by particles of sediment in the water. Furthermore, there is some evidence that certain bacteria may merely be inhibited in growth, rather than killed. Such bacteria, after a period of time, may recover and reproduce. If bacteria recover in the presence of fluorescent light, the process is known as *photoreactivation*.

Because ultraviolet irradiation does not involve the addition of chemicals, it leaves no residual. The costs in this process are the investment in equipment, electrical power consumption, replacement of ultraviolet bulbs and the occasional cleaning of the quartz sleeves around the bulbs.

• ***POU treatment***

Although the TDS concentration of rainwater is very low, if it is desirable to lower the TDS even more—for potable and culinary applications—a POU reverse osmosis (RO) system can be installed at a single tap. These systems are self-contained and include activated carbon filters and an RO membrane to reduce both ionic and organic contaminants.

Again, if the water is intended to be used as a potable supply, state and local codes, if any, must be met.

Conclusion

The looming shortages of usable water, combined with the simple design and low costs associated with rainwater harvesting systems, make this a no-brainer for water treatment professionals.

About the author

♦ *Peter S. Cartwright, CWS-VI, President of Cartwright Consulting Company, of Minneapolis is a registered Professional Engineer in Minnesota. He has been in the water treatment industry since 1974, has authored over 125 articles, presented over 125 lectures in conferences around the world and has been awarded three patents. Cartwright has chaired several WQA committees and task forces and has received the organization's Award of Merit. A member of WC&P Technical Review Committee since 1996, his expertise includes such high-technology separation processes as RO, UF, MF, UF electrodialysis, deionization, carbon adsorption, ozonation and distillation. Cartwright is also Technical Consultant to the Canadian Water Quality Association. He can be reached by phone (952) 854-4911; fax (952)854-6964; email pscartwright@msn.com or on his website; www.cartwright-consulting.com.*