Options for Rainwater Disinfection

By Jack Holmgreen

From traditional to cutting edge, rainwater disinfection technologies abound

With the increasing scarcity of clean water and growing popularity of rainwater harvesting, potable rainwater use is inevitable. It is often the cleanest feedstock for the production of drinking water, since it has fewer contaminants than surface water or groundwater in most cases. The main concern with making rainwater potable is the possibility that harmful microbes could be present.

A mistake that should be avoided is the use of chlorine or any other disinfectant in a rainwater cistern. Initially, chlorine or hydrogen peroxide should be used to ensure that no toxic microbes exist in the materials used to construct any surfaces that will come in contact with captured rainwater. This can be accomplished by rinsing and flushing the system before it is put into service.

After installation, the cistern should be allowed to build up a beneficial biofilm of naturally occurring microbes that will compete with any pathogens that may be introduced with each rain event. This is the natural process that purifies water in the environment as it trickles down to aquifers, and it should not be disturbed unless a specific event throws off the balance.

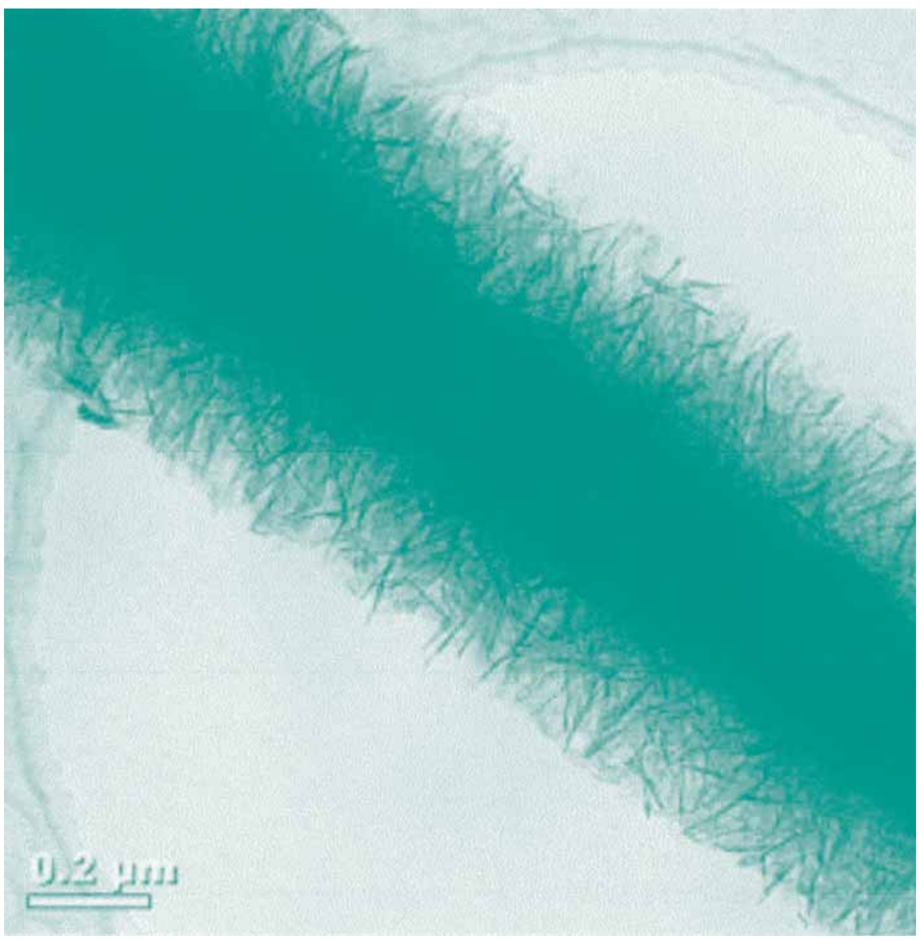
Disinfection is accomplished best at the point of entry to the building or at the point of potable use. However, more than 85% of the approximately 3 million domestic rainwater systems in use in Texas today do not disinfect at all.

A recent study conducted by researchers at Monash University in Australia on the health of families who drink rainwater found that it is safe to drink without disinfection. Karin Leder, associate professor with the university's department of epidemiology and preventive medicine, led the research in conjunction with Water Quality Research Australia. The study involved 300 volunteer households in Adelaide, Australia, that were given filters to treat their rainwater. Half of the filters were real, while half looked real but did not contain active elements.

"The results showed that rates of gastroenteritis between both groups were very similar," Leder said. "People who drank untreated rainwater displayed no measurable increase in illness compared to those that consumed the filtered rainwater."

Despite this finding, it is recommended that disinfection be used to protect against harmful microbes that could randomly be present, especially if the water is used in a public building. Many methods are available, and newer ones are being introduced to address issues like chlorine resistance and disinfection byproducts.

The most common technologies include boiling, iodine, chlorination, solarization, ultraviolet (UV) irradiation, ozonation, microfiltration and ultrafiltration. Newer technologies include nanoalumina, photodisinfection with high-intensity LED light, electrolyzed water, capacitive deionization, copper ion dispersion, hydrogen peroxide injection and solar electrolysis.



Nanoalumina bonded to microglass fibers attracts and holds microbes, allowing for higher flow rates and less pressure drop.

Traditional Methods

Boiling and iodine are well-known and inexpensive methods, but they leave water with a bad taste and can be tricky for novices. Chlorination can leave byproducts with unknown effects and certain cysts and some viruses are becoming resistant to it. Solarization, or simply exposing water to sunlight, is effective as long as the water is clear enough and the sun is bright enough, but it can be cumbersome and uncertain.

Irradiation with UV light produces minimal byproducts and provides disinfection of bacteria and most viruses, but it does not affect algae, and *Cryptosporidium* and *Giardia* may not be completely inactivated. UV systems are easy to install and fairly economical to operate and maintain.

For UV to be effective, water must have low turbidity, the crystal sleeve must be kept clean and the flow rate must be matched to system specifications. Most systems are class B, which provide a 16-mJ dose and are intended for supplemental disinfection of nonpathogenic organisms. For complete inactivation of *Giardia* and *Cryptosporidium*, a class A system supplying a minimum 40-mJ dose should be used.

Ozone has been used in Europe and other countries for some time but has not yet been widely adopted in the U.S. One notable exception is the city of Milwaukee, where a *Cryptosporidium* outbreak in 1993 sickened thousands, prompting a change from traditional chlorination to ozone and chlorine dioxide.

Ozonation is effective over a wide range of pH levels, kills algae and microbes, eliminates a variety of organic and inorganic compounds, and does not add any toxic chemicals to the water. It can produce some byproducts, most notably bromate, if bromine is present in the rainwater, but this is unlikely if the system is properly designed and maintained. Free ozone is toxic if it escapes into the air and could present a fire hazard in enclosed areas. Newer systems avoid this by injecting a low dose of 0.25% to 0.5% ozone produced by corona discharge directly into the water stream.

Microfiltration and ultrafiltration are mechanical filtration methods that differ primarily by pore size. Microfiltration uses 0.2-µ pores, while ultrafiltration pores go down to 0.02 µ.

Both methods remove cysts, protozoa and bacteria, but ultrafiltration also removes viruses. There is some pressure loss across the membrane and pretreatment is recommended, but no byproducts are produced and the organisms are removed, rather than killed or inactivated and left in the water. Only some of the systems have been certified for microbe removal, so check certifications before installing one for disinfection.

New Technologies

One of the newer technologies coming onto the market uses nano-alumina. It is usually bonded to microglass fibers and features 2- to 3-µm pores, which allow greater flow rates and less pressure drop because the microbes are attracted to the charged microfibers and held tightly. Backflushing is not necessary. This technique promises to be a good alternative that will not require energy input or increased pressure to work and will not depend on clarity, pH or temperature.

Another promising method is photodisinfection with high-intensity LED light. The new bulbs produce a more refined UV spectrum using less energy and can last longer than the typical one-year lifespan of current bulbs. Turbidity is still an issue and the bulbs are expensive initially, but they do not heat up water in the housing when the water is not flowing.

Electrolyzed water has some remarkable properties that are still being researched, and it could revolutionize water disinfection in the future. Anolyte and catholyte are produced by charged plates in a water column where ions are separated and collected. The catholyte contains positive cations, which have the ability to attract and bind to negatively charged microbes that are toxic to humans.

In experiments conducted by adding small quantities of catholyte to fouled wells, the wells became potable again, with reductions in microbes and contaminants in as little as 24 hours. Further study is needed, but with groundwater contamination increasing, this could be a useful development.

A similar technique is capacitive deionization, in which charged plates collect ions from a moving stream of water. The charges on the plates are then reversed and the collected ions are momentarily backflushed out of the system to produce deionized water. Minerals would have to be added to the resulting purified water before drinking, but the energy used is minimal compared to other methods.

Copper ion dispersion is being used by the swimming pool industry to replace chlorine, and it has potential in drinking water disinfection. When algae and bacteria come in contact with copper ions, they absorb them and die. The copper is complexed into the organic matter and is no longer measurable in the water, making it safe to drink. Research into virus removal is ongoing and shows potential.

Hydrogen peroxide has long been used for disinfection and can be particularly useful if a cistern lies dormant for long periods and becomes anaerobic. In the past, concentrations as high as 30% hydrogen peroxide were poured into the cistern and manually mixed to achieve uniform oxidation. Today, automated systems produce hydrogen peroxide on site and meter it into a contact vessel, much like hypochlorite. The water is then passed through activated carbon, resulting in clean-tasting, microbe-free water.

The most innovative method of purifying water may be solar electrolysis. Highly contaminated water is mechanically prefiltered and then electrolyzed by solar power into hydrogen and oxygen, leaving everything else behind in a concentrated sludge. The hydrogen is then burned, producing pure water and heat, which is recovered to run a steam generator to charge batteries at night. The system uses untreated water and sunlight to produce hydrogen, oxygen, heat, electricity and clean water.

No matter how you go about getting it, drinking water is one of the world's most valuable assets. The quality of the water you drink is ultimately your own responsibility and should not be taken lightly. State legislatures across the country are recognizing that rainwater harvesting is a big part of the answer to the water crisis the world faces, and they are promoting the practice with tax abatements and sometimes even cash rebates. There are at least six brands of bottled rainwater available for sale in the U.S. today. Look for it the next time you are thirsty—it is clean and healthy and tastes great. *wqp*

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