Membrane technologies enable water reclamation

Membrane technologies have potential to purify reclaimed water for a multitude of uses, says Dr. Francis DiGiano, professor of environmental sciences and engineering at Carolina's School of Public Health, who has investigated these technologies for the last 15 years.

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Dr. Francis DiGiano (above) displays two membrane filter samples in his laboratory at the UNC School of Public Health. The filter on the right is a hollow fiber microfilter (low-pressure) membrane cartridge formerly used in a drinking water treatment plant. The filter on the left is a reverse osmosis (high pressure) membrane unit. It is a small-scale unit designed for pilot-testing in water treatment plants. Full-scale units are 4 feet or longer and may be as large as 16 inches in diameter. Membrane technologies such as these have potential to purify reclaimed water for a multitude of uses. A close-up of the membranes is shown right.

"Membranes are made of either synthetic organic polymer or inorganic ceramic materials that hold back contaminants but have pores or open spaces that allow water to pass," DiGiano says. "They can remove high levels of particles, bacteria, viruses and trace organic chemicals from wastewater that is being reclaimed for reuse. Membrane technologies refer to the many ways that membrane material can be designed into large-scale treatment devices to purify millions of gallons of water each day."

Treatment designs can be tailored to fit specific water reclamation objectives, DiGiano says. For instance, membranes designed to remove bacteria and viruses can be used for treating reclaimed water intended for fighting fires in order to assure fire fighters of the water's safety. Nearly all chemical contaminants can be removed by certain membrane technologies to create reclaimed water fit for use even in microchip production.

"Membrane technology is essential to achieve the highest possible removal of trace levels of organic contaminants and viruses," DiGiano points out. "This is necessary in California and Arizona, for example, where reclaimed water is returned to the groundwater, and after natural purification and dilution with native groundwater, may eventually be withdrawn for water supply."

Membranes also can be used to improve upon conventional wastewater treatment techniques that depend on bacteria to biodegrade contaminants in the wastewater. In this process, known as "membrane bioreactor technology," membrane materials are formed into hollow fibers or flat sheets. DiGiano likens the fibers to bundles of bucatini, or hollow spaghetti, and the sheets to layers of lasagna. Either fibers or sheets are submerged into a tank in which high concentrations of bacterial cells are present.

"The membrane material holds back essentially all bacteria as well as other smaller particles that would otherwise escape conventional biological treatment plants," DiGiano says. "This is an important advantage to this technology."

Using membrane technology for water reclamation permits multiple uses of the same water, thus limiting withdrawals from clean drinking water resources. "In this way, our water resources are better preserved or sustained for future generations," DiGiano says. (See water reclamation article on page 28.) "In the extreme, closed-loop water recycling (pure water, to wastewater, to pure water, over and over again)—as practiced on space ships for non-potable (non-drinking) purposes—is the ideal goal of water sustainability."

Membrane bioreactors may be a key to global water sustainability, says DiGiano, emphasizing a point that he and 13 other water experts from around the world agreed upon at a 2003 conference DiGiano organized at the Rockefeller Study and Conference Center in Bellagio, Italy. During this time, DiGiano was a Fulbright scholar at the Milan Polytechnical University studying European membrane bioreactor technology.

"At the time, several western European countries had become early adopters of this technology, and the largest plant was in Brescia, Italy," DiGiano says. "I think that the largest plant is now in the U.S., but in fact, European countries tend to experiment more willingly with new technologies than the U.S."

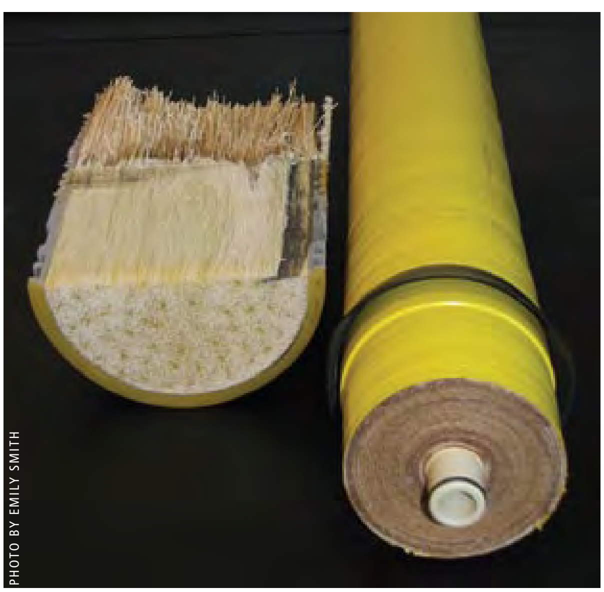
The Bellagio group agreed that affordability, small size and ease of operation make membrane bioreactors well-suited for water reclamation in developed and developing countries alike. While this technology has been available for about a decade, its potential for decentralized water reclamation in urban and suburban centers has been undervalued. Membrane designs typically require far less space and have more aesthetic appeal than traditional wastewater treatment facilities. Building small, decentralized membrane bioreactors avoids the expense of conveying water to a large, centralized wastewater treatment plant and subsequent return by long reclaimed-water pipelines for local reuse.

TIP: Save water by choosing a fuel-efficient vehicle. It takes 44 gallons of water to refine one gallon of crude oil.

DiGiano also has investigated membrane technologies closer to home. Last year, he completed a pilot project in Greensboro, N.C., to compare which low-pressure membrane technologies (microfiltration or ultrafiltration) could remove the most contaminants prior to treating the water with one of two high-pressure membrane technologies (nanofiltration or reverse osmosis). Contaminants can clog membranes and thus limit water flow through the filtration system.

"To carry the pasta analogy further, when membranes are used to treat wastewater, some of the contaminants that are removed stick to the membrane surface, just as tomato sauce would stick to spaghetti or lasagna," says DiGiano. "This prevents water from passing through and thus forces use of higher and higher pressure to produce the same amount of water each day. As the 'sauce' builds up, it finally becomes necessary to stop the process and remove it by chemical means. So, the engineering goal is to minimize the rate at which this foulant layer builds up so as to limit the number of times each year that the entire membrane system must be stopped and chemically cleaned to remove the 'tomato sauce.'"

"Membrane technology is essential to achieve the highest possible removal of trace levels of organic contaminants and viruses (from reclaimed water)."



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The fouling problem is particularly critical when nanofiltration or reverse osmosis are needed to produce very high-quality reclaimed water. These high pressure membranes have very small openings through which almost-pure water can pass, leaving behind more than 90 percent of the chemical contaminants and 99.9999 percent of viruses.

In the Greensboro study, effluent from the conventional wastewater treatment plant was passed through a pilot plant containing low- and high-pressure membranes in series. The high-pressure membranes make possible high removals of organic contaminants that would otherwise not occur. In studying two low-pressure membrane pretreatment processes (ultrafiltration and microfiltration), DiGiano found that ultrafiltration (which has pores ten times smaller than microfiltration) was the better pretreatment. "Still, some things passed through that caused fouling of the reverse osmosis membranes," says DiGiano, "so there is still room for improvement."

The study found that using either microfiltration or ultrafiltration in combination with high-pressure membranes (either nanofiltration or reverse osmosis) produced water with nearly complete elimination of viruses and greater than 90 percent removal of organic contaminants.

The system tested in Greensboro is much more expensive than using low-pressure membranes alone, DiGiano says. "You need to apply a lot of pressure to push the water through very tight polymeric structures that reject viruses and trace organic chemicals. But the benefit is higher quality water that could expand the range of opportunities for water reclamation," he says. ■