A Novel Technique for Wastewater Filtration in Space and on Earth

A clean water supply is essential to long-term space exploration and habitation. However, recycling wastewater to provide a safe and healthy water supply is a challenge onboard spacecraft. Dr. Richard Lueptow and his colleagues at Northwestern University are developing a water management system using rotating reverse osmosis membrane filtration that can be used in space and on Earth.

An efficient system for recycling wastewater is essential for all but the shortest duration manned space flights. Basic resources such as air and water must be recycled on a spacecraft to keep supplies fresh because storage capacity is limited and resupply from the ground, when possible at all, is very costly.

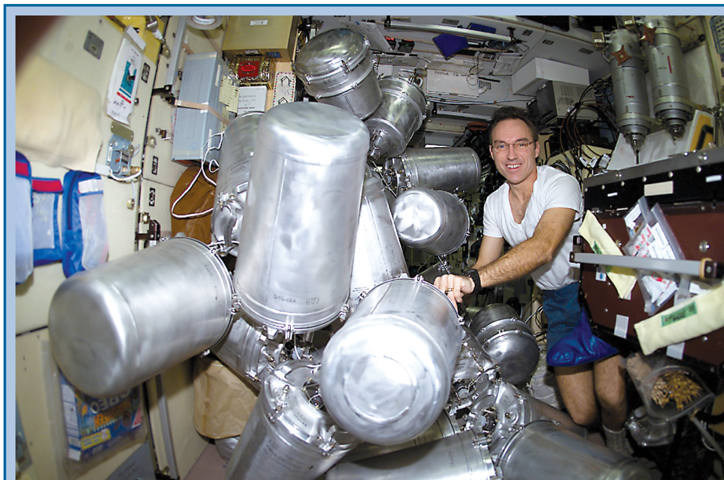
The water on spacecraft becomes polluted with waste hygiene water, condensate, and urine from crew members. There are various methods of purifying wastewater on Earth including biological treatment, chemical treatment, and reverse osmosis, which filters out chemical species. The challenge for NASA is to develop an efficient system that requires minimal energy and space for use on spacecraft.

Pairing Two Filtration Techniques

Dr. Richard Lueptow and his team at the Department of Mechanical Engineering at Northwestern University envisioned a way to improve water filtration techniques onboard spacecraft by using rotating filtration. Originally used in blood filtering, Lueptow thought that this system would work for wastewater treatment or drinking water purification. The system had the potential to reduce equipment size, increase throughput, and lower energy requirements.

"Rotating filtration," Lueptow explains, "is a system that uses a cylindrical filter that is set in motion within an outer cylinder. The fluid that is to be filtered is introduced under pressure between the rotating inner cylinder (the filter), and the outer cylinder. The fluid component flows through the filter and is collected from inside that spinning cylinder. The stuff that stays in between the inner and outer cylinders is the waste product."

About three years ago, Lueptow and his team began to develop a combination rotating filtration-reverse osmosis system. The technique of rotating filtration had been applied to microfiltration, but never to reverse osmosis due to technical issues stemming from the pressures involved.



Astronaut Carl E. Walz, Expedition Four flight engineer, catalogs canisters of water in the Zvezda Service Module on the International Space Station. (NASA photo ISS004-E-9650.)

From Wastewater to Drinking Water

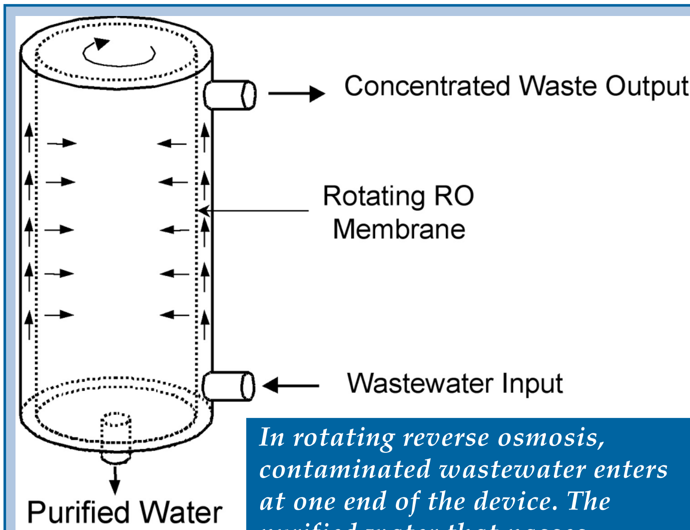
The reverse osmosis membrane has tiny pores, less than a billionth of a meter in size, which are small enough so that water can filter through but contaminants such as urea and ammonia cannot. By mounting the reverse osmosis membrane on this cylindrical rotating system, Lueptow's team discovered that reverse osmosis technology is enhanced in several ways. The rotation keeps the water moving, washing the chemicals away from the pores. This helps to prevent the filter from becoming clogged. Each filter lasts longer, reducing the frequency of replacements and the size of the filter supply required onboard the spacecraft. The system allows higher flow rates so smaller filters can be used. The rotation also increases what is called the rejection rate. A high rejection rate means that fewer contaminants pass through the filter. The rotational washing of contaminants away from the membrane increases the system's efficiency by increasing the rejection rate and the flow through the filter.

Wastewater produced on a spacecraft would need to pass through the reverse osmosis filter about three times to be acceptable as drinking water. To achieve this result, several devices might be placed in a series. "The advantage is the first one cleans up most of the big junk, then the next takes care of the details," Lueptow explains. But the reverse osmosis is just part of a larger system. "Wastewater would come into a holding tank and from there it would go into a microfiltration system to remove the particles. From there it would go into the first stage of a reverse osmosis system to remove 90 percent of the chemicals, then to the second stage to remove 90 percent of what was left, and then to a third stage to remove another 90 percent."

About a year ago, the team obtained data proving that the system works. They now have a functional prototype that can provide one quarter of the daily water requirement of an astronaut. (Water usage is about 30 kg per day per person; this system is sized to handle about 7.5 kg per day.) Continued testing will investigate two aspects of system function. First, they are testing the effect of the rotation system on scale buildup. Data indicate that the rotating system minimizes this buildup because it constantly washes scale-forming compounds away from surfaces. Secondly, they are testing the effect of the system when particles are present in the water. They are finding that particles may reduce the flow rate through the filter at low rotational speeds.

Creating a Fully Operational System

Now that the concept of applying rotation to reverse osmosis has been proven, there are several steps to be taken before the system is ready to fly in space. Lueptow's team plans to develop a second-generation prototype that overcomes some of the challenges to the rotating system. The two main problems are (a) the rotating seal, which poses difficulties because the system has to operate at a relatively high pressure, and (b) mounting of the reverse osmosis membrane in a cylindrical shape, which is problematic since the membrane is fabricated as a flat sheet. The system will undergo long-term testing, and the team still needs to resolve how to integrate the rotating reverse osmosis technique into an overall waste treatment system suitable for a spacecraft. Design issues include energy requirements, volume requirements, and scaling up the system to support several astronauts.



In rotating reverse osmosis, contaminated wastewater enters at one end of the device. The purified water that passes through the reverse osmosis membrane is collected via the center of the cylinder. Highly concentrated waste is removed at the opposite end of the device.

The prototype rotating reverse osmosis system can produce about 1/4 of the water that an astronaut would need each day.

Within the next three years, Lueptow hopes to accomplish his goal of creating a highly reliable yet small system that can be used for cleaning the wastewater expected to be produced onboard a spacecraft. And with a patent filing underway, the university expects to have spinoffs for ground-based applications. "In fact, anywhere one uses reverse osmosis now, one could use rotating reverse osmosis. The advantage is the smaller size and more efficient removal of contaminants. Applications can be anything from desalination to treatment of industrial effluent," says Lueptow.

References

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