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Instruments

Colorimetric-Solid Phase Extraction for In-Flight Water Analysis (C-SPE)

We all need water, but nothing drives the point home like living in the International Space Station (ISS). Each crew member there requires a minimum of 3 liters (about 3 quarts) of water per day. One liter is electrolyzed to produce oxygen, and 2 liters go for drinking, hygiene, food rehydration, and other miscellaneous uses. That's minimum.

ISS Expedition 8 mission commander Michael Foale fills a bag from the potable water dispenser.

Currently, all crew members (up to 3) share a single water-processor assembly, galley and toilet in the Russian section of the space station, but that will not be enough for the targeted 6-person crew. So an additional facility is scheduled to be installed in the American segment in January, 2009.

Recycling water is key to keeping the ISS livable and affordable. A crew of 6 would need at least 7 tons of water per year -- an extremely expensive proposition if it all had to be launched from Earth.

The Russian system captures and recycles condensate from a dehumidifier. The American system will have the additional capability of recycling urine. Purification makes the water fit for consumption, but it needs to be stored with a biocide to keep it that way. The Russian system uses silver ions for this purpose and the American version will use iodine. NASA is currently planning to move to silver for the Crew Exploration Vehicle (known as Orion) that will replace the space shuttle and ferry astronauts to the Moon.

There are two points at which it is vital to measure the concentration of these substances in the water. While the water is stored, it's important to ensure that the biocide levels do not drop below the level necessary to inhibit the growth of microbes, since the amount of these chemicals can potentially be reduced through adsorption into the tubing through which the water travels, reaction with other chemicals in the water, and other mechanisms. Then, before the water is consumed, it's important to make sure that the biocide has been filtered out of the water. Too much iodine can cause thyroid dysfunction. Too much silver can cause an irreversible blue-gray discoloration of the skin known as argyria.

The colorimetric-solid phase extraction (C-SPE) instrument will enable ISS astronauts to quickly and easily determine the biocide levels in their water both before and after the biocide-filtration process. A test mission on the space station, lasting about 6 months, is scheduled to begin shortly after the American facility is installed.

How it works

An astronaut releases water into a bag, and then draws a measured amount into a special syringe (plastic for silver, or glass encased in plastic for iodine). A small cartridge containing a membrane impregnated with a **colorimetric reagent** -- a chemical that changes color in the presence of the substance being measured -- is attached to the syringe, and the water is pushed through it. Using a handheld spectrophotometer, the astronaut measures the degree of color change in the membrane, which reveals the level of biocide in the water. The whole procedure takes about one minute.

The C-SPE equipment consists of a portable reflectance spectrophotometer (blue), a syringe, colorimetric membranes (inset), and an attachment that enables water to be pushed from the syringe through the desired membrane.

The C-SPE system can detect as little as 0.005 milligrams per liter (mg/L) of silver ions and 0.1 mg/L of iodine. Future versions are expected to be able to detect viruses and bacteria as well as various toxic materials that could potentially find their way into the water supply.

Development

To learn how to make C-SPE work in microgravity, the development team engaged the KC-135, an airplane that simulates "weightlessness" by flying through a series of parabolic arcs. The plane climbs steeply and then dives just as steeply, over and over. During the dives, everyone and everything within the plane are in freefall. Essentially, they are skydiving -- except that, since the air in the plane is falling at the same rate as everything else, there is no wind resistance. The stresses on passengers of repeatedly climbing and diving have earned the aircraft the nickname, "the Vomit Comet."

"The first Vomit Comet flight was really just vomiting," said Marc Porter, who is the C-SPE's principle investigator and part of a team of scientists and engineers from Arizona State University, Iowa State University and NASA's Johnson Space Center. "We really didn't get much done on that one at all." But in the course of four flights, Porter's team mastered the microgravity environment.

One major problem was finding a way to remove air bubbles from the water sample. In microgravity, they don't float to the top. Porter's team developed a technique for easily kneading the sample bag with their fingers and massaging the bubbles out of the water.

Interestingly, the space-age C-SPE grew out of a very down-to-Earth application. "This instrument was developed by the surface-finishing industry to monitor the color of the paint, intensity of the paint, how matte the surface would be, all those kinds of parameters," Porter explained. "We took it and adapted it to do what we want to do."

Links:

- Plumbing the Space Station
- Water on the Space Station

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