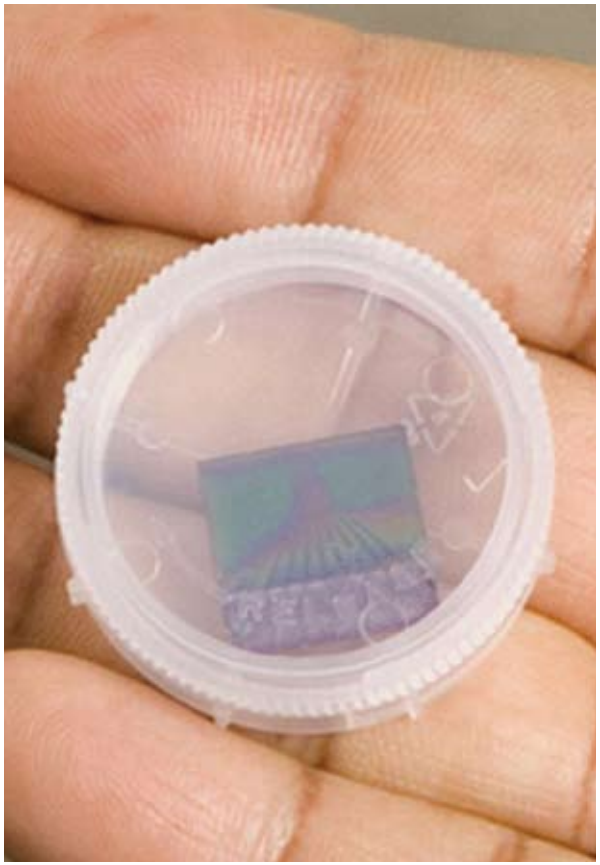
Sensors Provide Early Warning of Biological Threats

Originating Technology/NASA Contribution

The Centers for Disease Control and Prevention (CDC) estimates there are between 4 and 11 million cases of acute gastrointestinal illnesses in the United States each year—caused by pathogens in public drinking water. The bacteria *Escherichia coli (E. coli)* and *Salmonella* have within the past few years contaminated spinach and tomato supplies, leading to nationwide health scares. Elsewhere, waterborne diseases are devastating populations in developing countries like Zimbabwe, where a cholera epidemic erupted in 2008 and claimed over 4,000 lives.

Scientists have found an unexpected source of inspiration in the effort to prevent similar disasters: the search for life on Mars. The possibility of life on the Red Planet has been a subject of popular and scientific fascination since the 19th century. While Martian meteorites have turned up controversial hints of organic activity, and NASA's exploratory efforts have delivered important discoveries related to potential life—the presence of water ice, and plumes of methane in Mars's atmosphere—direct evidence of organisms on our closest planetary relative has yet to be found.

In order to help detect biological traces on Mars, scientists at Ames Research Center began work on an ultrasensitive biosensor in 2002. The chief components of the sensor are carbon nanotubes, which are the major focus of research at the Center for Nanotechnology at Ames—the U.S. Government's largest nanotechnology research group and one of the largest in the world. Tubes of graphite about 1/50,000th the diameter of a human hair, carbon nanotubes can be grown up to several millimeters in length and display remarkable properties. They possess extreme tensile strength (the equivalent of a cable 1 millimeter in diameter supporting nearly 14,000 pounds) and are excellent conductors of heat and electricity.



Containing millions of carbon nanotubes, the NASA biosensor can alert inspectors to minute amounts of potentially dangerous organic contaminants.

It is the nanotubes' electrical properties that Ames researchers employed in creating the biosensor. The sensor contains a bioreceptor made of nanotubes tipped with single strands of nucleic acid of waterborne pathogens, such as *E. coli* and *Cryptosporidium*. When the probe strand contacts a matching strand from the environment, it binds into a double helix, releasing a faint electrical charge that the nanotube conducts to the sensor's transducer, signaling the presence of the specific pathogens found in the water. Because the sensor contains millions of nanotubes, it is highly sensitive to even minute amounts of its target substance. Tiny, requiring little energy and no laboratory expertise, the sensor is ideal for use in space and, as it turns out, on Earth as well.

The water analysis process takes about 2 hours, a drastic improvement over typical laboratory-based water sampling, which can take several days.

Partnership

"Carbon nanotubes are the wonder material of nanotechnology," says Neil Gordon, president of Early Warning Inc., based in Troy, New York. "The opportunity was ripe to put that technology into a product." Gordon encountered the director of the Center for Nanotechnology, Meyya Meyyappan, at a number of industry conferences, and the two discussed the possible terrestrial applications of NASA's biosensor. In 2007, Early Warning exclusively licensed the biosensor from Ames and entered into a Space Act Agreement to support further, joint development of the sensor through 2012.

Product Outcome

Early Warning initially developed a working version of the NASA biosensor calibrated to detect the bacteria strain *E. coli* O157:H7, known to cause acute gastrointestinal illness. It also detects indicator *E. coli*, commonly used in water testing. In the process, the company worked out a method for placing multiple sensors on a single wafer, allowing for mass production and cost-effective testing. In April, at the 2009 American Water Works Association "Water Security Congress," Early Warning launched its commercial Biohazard Water Analyzer, which builds upon the licensed NASA biosensor and can be configured to test for a suite of waterborne pathogens including

E. coli, *Cryptosporidium*, *Giardia*, and other bacteria, viruses, and parasitic protozoa. The analyzer uses a biomolecule concentrator—an Early Warning invention—to reduce a 10-liter water sample to 1 milliliter in about 45 minutes. The concentrated sample is then processed and fed to the biosensor. The entire process takes about 2 hours, a drastic improvement over typical laboratory-based water sampling, which can take several days to a week. The sensor operates in the field via a wired or wireless network and without the need for a laboratory or technicians, allowing for rapid, on-the-fly detection and treatment of potentially dangerous organic contaminants.

"The sensor is incredibly sensitive and specific to the type of pathogen it is calibrated to detect in the water," says Gordon. "Instead of just detecting coliforms in the water that may or may not indicate the presence of pathogens, we will know if there are infectious strains of *Salmonella*, *E. coli*, or *Giardia* that could sicken or even kill vulnerable people if consumed." (Coliform bacteria levels typically indicate water and food sanitation quality.)

The water analyzer has multiple applications, notes Gordon. Early Warning's system can monitor recreational water quality at beaches and lakes, which can be contaminated by animal feces, farming activities, and infectious pathogens in human waste. Agricultural companies may use the analyzer to test feed water for cattle, and food and beverage companies may employ the sensor to ensure the purity of water used in their products. Health care organizations have expressed interest in using the analyzer to test water from showers and other potential sources of pathogens like *Legionella*, which causes the flu-like Legionnaires' disease.

Early Warning and Kansas State University, in Manhattan, Kansas, are collaborating on sensor enhancements such as improving the safety of imported produce. Since the skins of fruits and vegetables are potential sites of dangerous pathogens, inspectors could collect water sprayed on the produce and, using the analyzer, know within a few hours whether a particular shipment is contaminated. Last year, Kansas State was selected as the home for the U.S. Department of Homeland Security's new National Bio and Agro-Defense Facility, which could also benefit Early Warning.

Early Warning's analyzer feeds a concentrated water sample to its biosensor, providing rapid pathogen detection.

"We're eager to show how the private sector, government agencies, and academia can work together to evolve this platform into products that benefit our citizens," says Gordon. With an aging U.S. water and wastewater infrastructure, increasingly severe weather systems, global travel and food imports affecting the proliferation of disease-causing organisms, and more than 1 billion people worldwide without access to safe water (according to the World Health Organization), the fruits of this partnership may be more necessary than ever. ❖