# Small Sensors Promise Big Impact

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Last year around this time, this column highlighted a few promising environmental applications of nanotechnology. Since then, there has been an appreciable upswing in new products developed and commercialized pertinent to "intelligent" water monitoring tools and devices involving nanotechnology. Because many environmental applications of nanotechnology will almost certainly revolutionize the science, law, and regulation of water pollution, readers are urged to keep abreast of this fast-changing area.

## Background

Nanotechnology broadly refers to the study and use of materials and structures at the nanoscale level of 100 nanometers or less. Nanotechnology connotes less a single "technology" than a generic term for a large and diverse number of applications and products that contain small particles and demonstrate special properties. The U.S. Environmental Protection Agency (EPA) and other federal agencies and entities recognize the enormous potential of nanotechnology for creating cost efficient, sustainable and efficient tools for addressing water supply challenges. Applications include, for example, ground water and surface water treatment and remediation, desalination, purification, wastewater recycling, disinfection and filtration, and, of most relevance to this column, real-time and remote water monitoring. Advances "in nano-based environmental monitoring will lead to real-time, rapid, multimedia measurements of thousands of pollutants," says the National Nanotechnology Coordinating Office (NNCO), a subgroup of the Nanoscale Science, Engineering, and Technology (NSET) subcommittee. "The ability to mine this immense database will provide epidemiologists with an unprecedented ability to associate adverse health effects associated with exposures to complex mixtures of pollutants (Nanotechnology Grand Challenge in the Environment, May 2003)."

## Applications achieving results

The EPA Office of Research and Development (ORD), through its National Center for Environmental Research (NCER), funds Science to Achieve Results (STAR) research grants (http://es.epa.gov/ncer). More than $11 million in grant money has been devoted to the application of nanotechnologies to achieve environmental protection, some of which has been directed to water monitoring research. EPA also awards contracts to small companies through its Small Business Innovation Research Program to help develop and commercialize nanomaterials and clean technologies.

A few noteworthy examples: Arizona State University (ASU) researchers, working under a STAR grant, are developing high-performance, low-cost sensors for onsite screening of metals in ground and surface water. These sensors will be miniaturized and wireless. Prototype sensors are expected to be field tested next year. Each sensor consists of an array of nanoelectrode pairs placed on a silicon chip. According to a publicly available write up of the technology, "Within each pair, the nanoelectrodes are separated by an atomicscale gap created by quantum tunneling … Electrochemical deposition of only a few metal ions into the gap forms a bridge and provides nanocontact between the electrodes, thus triggering a quantum jump in electrical conductance… This allows the sensor to achieve high specificity by combining measurements such as redox potentials, point-contact spectroscopy, and electrochemical potential-modulated conductance changes (http://clu-in.org/products/newsltrs/tnandt/vie.cfm?issue=0905.cfm)."

ASU researchers also are developing "a similar field-portable sensor for use in monitoring air quality and arsenic in ground water, as well as other molecular- and nanojunction-based chemical and biological sensors based on carbon nanotube and polymer technologies (http://clu-in.org/products/newsltrs/tnandt/vie.cfm?issue=0905.cfm."

EPA's STAR website reveals many other applications and nanotechnology-based water monitoring tools about which readers may wish to learn more.

## Implications

Nano-based technologies will continue to garner significant attention in the years to come. Environmental sciences experts will need to keep current with these evolving technologies to know how to select the appropriate tools for the job, and to thoroughly understand the environmental, biological, regulatory and legal implications of the applications of these newly available tools to environmental settings. How these tools will be peer reviewed, whether they'll be deemed acceptable for regulatory purposes, and how they'll be validated for use in particular applications, among other issues, are questions that remain unanswered. Environmental professionals must stay ahead of the debate to know what the key issues are and to be able to comment and participate in the development of an appropriate science-based framework for resolving these issues. Only then will the real promise of nanotechnology be realized, and its enormous utility for improving the environment be put to good use.

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