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November 5, 2012

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2012 Clarke Prize Lecture Focuses on Potential of Nanotechnology to Enhance Water Disinfection and Improve Microbial Control

FOUNTAIN VALLEY, Calif. – The 2012 NWRI Athalie Richardson Irvine Clarke Prize recipient, Pedro J.J. Alvarez, Ph.D., P.E., DEE, of Rice University, highlighted the opportunities of nanotechnology to develop next-generation applications for drinking water disinfection and safe wastewater reuse at the Nineteenth Annual NWRI Clarke Prize Lecture and Award Ceremony, held by the National Water Research Institute (NWRI) of Fountain Valley, California, on Friday, November 2, 2012, in Newport Beach, California.

Alvarez is the George R. Brown Professor of Engineering at Rice University in Houston, Texas. "Dr. Alvarez was the unanimous choice for this year's Clarke Prize," said Jeff Mosher, Executive Director of NWRI. "He was selected as the 2012 recipient because of his global leadership and outstanding contributions to enhancing water resource sustainability through water pollution control, specifically in the areas of bioremediation and environmental nanotechnology."

Consisting of a medallion and $50,000 award, the Clarke Prize is given out each year to recognize research accomplishments that solve real-world water problems and to highlight the importance of and need to continue funding this type of research. Alvarez was presented with the Clarke Prize by James Irvine Swinden of the Joan Irvine Smith and Athalie R. Clarke Foundation, which helped established and supports the Prize.

He also received a special acknowledgment from the California Latino Water Coalition, who lauded his accomplishments as "an inspiration to millions of Latinos to further their education and pursue such professional careers as innovators, scientists, mathematicians and engineers." Sylvia Ballin, who is the Coalition's Foundation Chair and a member of the Board of Directors of the Metropolitan Water District of Southern California, presented the Coalition's congratulations at the Lecture and Award Ceremony.

An environmental engineer, Alvarez focused his 2012 Clarke Prize Lecture on the topic of *Convergence of Nanotechnology and Microbiology: Emerging Opportunities for Water Disinfection, Microbial Control, and Integrated Urban Water Management*. Nanotechnology is an emerging field that involves the use of technology at the molecular level (at dimensions between 1 to 100 nanometers; for reference, 1 nanometer is 40,000 times smaller than the thickness of a human hair).

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According to Alvarez, one area of water treatment that has significant potential to be improved by nanotechnology is microbial control. Microorganisms such as viruses, bacteria, and protozoa are the leading cause of waterborne disease worldwide. In the United States alone, over 100 outbreaks and 5,000 recent cases of illness were caused by waterborne pathogens; the problem is worse in developing countries. Public health, however, is not the only area impacted by microorganisms. They can also increase costs and affect critical operations in the industrial sector. For instance, the oil and gas industry spends over $2 billion a year addressing biocorrosion caused by microbes.

Treatment technologies do exist to combat microorganisms. However, traditional solutions like chlorination and ozonation (which add chemicals to disinfect water) produce disinfection byproducts that could potentially harm public health and the environment and/or need further treatment to remove. These solutions are also limited in their abilities to address problems faced by aging water infrastructure, such as biofouling – which impairs the taste and odor of water, corrodes pipes, and contributes to energy loss during water flow and membrane filtration.

"These challenges underscore the need for new technologies and water management approaches that provide practical solutions for clean water," said Alvarez. "The importance of enhancing water disinfection and microbial control cannot be overstated."

Some nanomaterials have antimicrobial properties, which can be used to enhance existing treatment processes or develop new processes for microbial control. According to Alvarez, certain nanoparticles can directly inactivate microorganisms using a wide variety of mechanisms, such as damaging cell membranes or DNA. Others act indirectly by producing secondary products that serve as disinfection agents.

An example of an antimicrobial nanoparticle is AgNP, which stands for "silver nanoparticle." "Silver," said Alvarez, "was a prevalent antibiotic before the advent of penicillin." The silver ion (Ag^+) in AgNPs can effect microbial cell respiration and create stress on cell generation. Other examples of antimicrobial nanoparticles include titanium dioxide (its antibacterial effect works best under ultraviolet light) and zinc oxide (it inhibits microbial growth and generates hydrogen peroxide, which has antimicrobial properties).

In addition to having antimicrobial properties, many nanoparticles have "desirable properties for water and wastewater treatment," said Alvarez, including:

- Highly specific surface are for adsorption.
- High catalytic activity to destroy recalcitrant pollutants.
- Superparamagnetism for particle separation and reuse.
- Optical and electronic properties to develop selective sensors for water quality monitoring.
- No production of disinfection byproducts.

At the moment, most nanotechnology-enabled applications are at an early stage of development and potential barriers exist for widespread implementation. The high costs of nanomaterials are a critical factor, especially in developing countries. However, opportunities exist to reduce the costs, such as using nanomaterials of lower purity and reusing nanomaterials. Another challenge is the potential impact to human or environmental health due to an accidental release of nanomaterials. A risk assessment of nanomaterials in the environment is needed to assess potential threats, while technology measures are needed to prevent exposure to nanomaterials (such as immobilization or filtration through membranes or magnetic separation).

“Despite potential barriers,” concluded Alvarez, “nanotechnology will be increasingly relied upon for needed innovations in water treatment and reuse. Ensuring reliable access to safe and affordable water is one of the greatest challenges of the twenty-first century, and nanotechnology will likely play a critical role in addressing this challenge. Interdisciplinary research between microbiology and nanotechnology will be particularly important to develop high performance and greener disinfection and microbial control technologies for safer, broadly accessible, and more affordable water supplies worldwide.”

Alvarez is the nineteenth recipient of the NWRI Clarke Prize. He began his career in the mid-1980s, making advancements in understanding the practice of bioremediation, a water treatment process that involves using microorganisms to remove contaminants from water supplies. Since joining Rice University in 2004, Alvarez has taken the lead in evaluating the environmental impacts of nanotechnology, studying the fate, transport, and impact of a number of nanomaterials in the environment (a unique approach that includes examining both the benefits that may be produced from nanomaterials and any risks these materials may later pose to human health and safety). He is also examining the response of microorganisms to exposure to nanomaterials. His papers on the subject of environmental implications of nanotechnology are among the most widely read and cited in the water industry.

Copies of the 2012 Clarke Lecture may be downloaded at www.nwri-usa.org/laureates.htm.

A 501c3 nonprofit, the National Water Research Institute (NWRI) was founded in 1991 by a group of California water and wastewater agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection, maintenance, and restoration of water supplies and to protect the freshwater and marine environments through the development of cooperative research work. NWRI's member agencies include Inland Empire Utilities Agency, Irvine Ranch Water District, Los Angeles Department of Water and Power, Orange County Sanitation District, Orange County Water District, and West Basin Municipal Water District.

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