The 2001 Clarke Prize Honoree

Joan B. Rose, Ph.D.

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For more than 20 years, Dr. Joan Rose has made groundbreaking advances in understanding water quality and protecting public health. She is widely regarded as the world's foremost authority on the micro-organism *Cryptosporidium* and was the first person to present a method for detecting this important pathogen in water supplies. She was also the principal investigator during the deadly outbreak of *Cryptosporidium* in Milwaukee, Wisconsin, and in Carrollton, Georgia.

Dr. Rose has published more than 200 papers and articles on microbial water-quality issues. She has also advised Congress during the reauthorization of the *Safe Drinking Water Act* and was named as one of the 21 most influential people in water in the twenty-first century by *Water Technology Magazine* (2000). Currently, she is one of only a handful of scientists in the world today who are examining the relationship between climate, water quality, and public health. She is also involved in studies on the safety of coastal waters, and her findings have been instrumental in efforts to change wastewater management in the Florida Keys.

Dr. Rose received her bachelor's degree in microbiology from the University of Arizona in 1976, a master's degree in microbiology from the University of Wyoming in 1980, and a Ph.D. in microbiology from the University of Arizona in 1985. She has been a professor of Water Microbiology at the University of South Florida since 1989.

The 2001 Clarke Lecture

The Unseen Challenge to Safe Water: Microbiology of Water

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Hippocrates (460-354 BC) wrote in Air, Water, and Places,
"Qualities of the waters differ from one another in taste and weight, so they differ much in their other qualities. One should consider the water that the inhabitants use, whether they be marshy and soft or hard and running from elevated and rocky situations and then if saltish and unfit for cooking, for water contributes much to health."

On this day, like every other day, the people of the world will use nearly 3 trillion gallons of water. For one-fifth of the world's population, this water will be unsafe to drink because of microorganisms that contaminate the water. There is a critical relationship between water and health. Indeed, access to safe drinking water is one of the most serious public health crises facing the world. It is hard to believe that more than one billion people are at risk of disease and even death from the water that they drink.

Developing nations are still plagued by waterborne diseases, such as cholera, resulting in millions of deaths per year. Although many developed nations like the U.S. have dramatically reduced waterborne disease because of a century's advancements in treatments, the risk of waterborne disease remains a constant and cannot be ignored. Approximately 10 to 12 outbreaks occur per year in the United States, and these are the plane crashes for the water industry and represent only 10 percent of the true level of risk of waterborne disease.

World Wide

- According to the World Health Organization (WHO), every 8 seconds, a child dies from a water-related disease — that is nearly 11,000 children per day.
- Globally, infectious diseases, such as waterborne diseases, are the number one killer of children under five.

- The United Nations warns that 80 percent of diseases in developing countries result from unsafe water.
- More people die from unsafe water annually than from all forms of violence, including war.
- According to WHO, the water consumed by more than one billion people — one out of five on Earth — is unsafe, potentially leading to disease and death.

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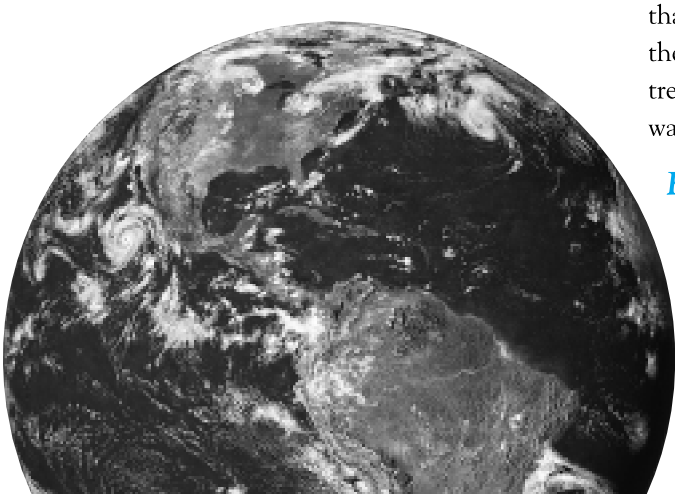
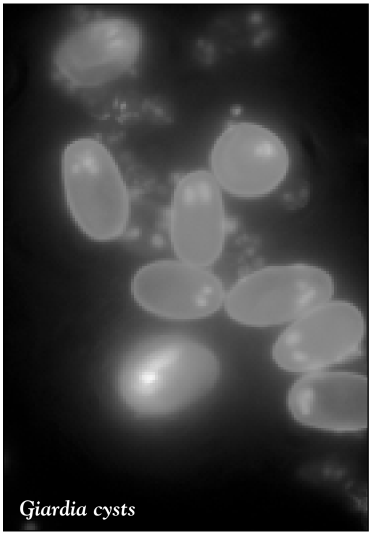
Water is intimately connected through the water cycle to our lives, not just to drinking water, but also in the way we manage human and animal wastes, food production, and recreation. The world's water problems have become a common global challenge. Why should we care that between 30 and 80 percent of the populations in Central and South America may be sewered, with only 5 to 10 percent having treatment? Because disease can easily be spread around the world in less than a day. For example, the introduction of a microorganism from ballast waters in key areas can spread like wildfire; such was the case of cholera in South and Central America in the early 1990s. In one year, the disease — which had not been present before in that region — spread to every country, causing millions of illnesses. This epidemic touched the world, though hardest hit were the poor. Take the case of *Cyclospora*, a protozoan parasite that first arrived in North American in 1995 and is associated with imported produce, causing widespread disease.



Global tourism, the global food market, and global economics are necessitating a common goal for the definition of safe water (from beaches to irrigation waters to drinking waters). While some have argued in the past that sanitation is of lesser importance than access to safe drinking water, it should be clear at this point that quantity and quality cannot be separated. The protection of coastal waters, ground waters, and fresh surface waters are intricately linked to economic and public health and, thus, to global health. Humanity dictates that we continue to strive toward safe water for the world's populations through wastewater treatment, protection of waters, and drinking water treatment.

Emerging Problems in the United States

The control of water pollution in the United States in the last two decades has focused on chemical risks and, while great strides have been made, risks associated with microbial pollutants have seen a continuance, reemer-



Giardia cysts

gence, and escalation. Sensitive populations in the United States, including the elderly, pregnant women, young children, and infants as well as the immunocompromised (e.g., cancer patients), are at the greatest risk of severe outcomes, hospitalizations, and death. The *Safe Drinking Water Act* states that the sensitive populations must be protected and may represent approximately 25 percent of the population of the United States at any given time.

The list of microorganisms that can be transmitted through contaminated water is long, and emerging pathogens continue to be of concern. The United States Environmental Protection Agency (EPA) has come up with a list known as the "Contaminant Candidate List" (CCL) of microorganisms that will need to be addressed in the future, including bacteria, viruses, and protozoa. While the first CCL has been published, the second list will be produced in the next few years, and we are already behind in addressing the occurrence and health risks associated with this growing list of microorganisms.

There are over 100 different types of bacteria, protozoa, and viruses that can be found in contaminated water. Groundwater has proven a risk for *E. coli* H0157, which has caused serious illnesses and kidney failure. Degenerative heart disease and insulin-dependent diabetes are caused by coxsackievirus B infections; coxsackievirus B is a common virus isolated from contaminated water. Peptic ulcers and stomach cancer are caused by the bacterium *Helicobacter pylori*, which has been linked to water in a number of studies. Besides *Cryptosporidium*, there are *Cyclospora* and *Toxoplasma*, which also produce oocysts that are extremely resistant to disinfection. There is concern about the transmission of antibiotic resistance through water. The recent outbreak of *Salmonella typhimurium* (a fecal-oral pathogenic bacterium), which caused illness in both cattle and humans, is alarming as this bacterium carries with it multiple antibiotic resistance.

In addition, there are new organisms on the horizon. For instance, *Tropheryma whippelii*, an actinomycete, is detected in sewage and is the cause of Whipple's disease. Nanobacteria are an unknown group of organisms shed in urine that may be associated with kidney stones. For both of these organisms, waterborne transmission is uncertain. Despite a growing uneasiness, most states have been unable to develop comprehensive monitoring programs that will lead to the protection of water resources for the future.

Maintaining water quality and drinking water safety is becoming more critical than ever before. Water quantity has been the focus of most investigations and debates, and drinking water utilities are facing numerous water quality challenges in the future. The "Enhanced Surface Water Treatment Rule" will address the protozoa, particularly *Cryptosporidium* and viruses as well as groundwater under the influence. The "Groundwater Rule" will address disinfection and the control of viruses and *Legionella*. The balance of risk between microorganisms and disinfection

will continue to be debated within the development of the "Stage II Disinfectants, Disinfectant By-Products" rule. One of the greatest challenges the water industry will face is water quality in the distribution system.

More recently, we have turned our attentions to our beaches. Nationwide, 729 beaches were closed for at least one day in the summer of 1998. In total, more than 7,000 beach days were lost, mostly in New Jersey, California, and Florida. Almost every coastal and Great Lakes state reported having at least one beach where storm water was a known source of pollution at or near bathing beaches. Interestingly, because of the time delay in regard to identifying the problem, the beaches were generally opened on the days of the contamination event and closed even when the water quality had improved.

The sources of the problems in the United States often appear to be non-point sources, animal feeding lots, septic tanks, combined sewer overflows, and storm waters. Investigations of drinking water and coastal waters suggest that rainfall is a driver in transporting the contamination from its sources and to the site of public health risk of exposure. It is clear that these sources are more difficult to deal with and control. In addition, risks from naturally occurring harmful aquatic organisms, such as toxic algae, have yet to be clearly identified, and again, controls of the risk are not clear-cut.

New Tools

In the era of the Human Genome Project and the announcement of the complete sequencing of the genetic information that makes up a human being, it is clear that the tools for characterizing microorganisms exist. This genetic assessment also leads to the knowledge of proteins and functions — in this case, the potential for causing waterborne disease. Identification of the microbial hazards, occurrence, transport, and control can all be addressed with the new methods available. Methods that can be automated through the development of instrumentation can be made field-ready. Our biggest challenges will be in building consensus methods and databases and in interpreting data.

- *Source Tracking:* Some molecular techniques are particularly promising as a means to identify the source of a contaminant. Without source identification, contamination may not be contained. Molecular fingerprints, host-specific genes, and chemical constituents provide direct evidence of source origin, while general indicators provide virtually no information about source.
- *Pathogen Identification:* In order to begin to identify risk, the type of pathogen present should be identified and quantified. In most cases, pathogens are non-cultivatible, and polymerase chain reaction (the system used to copy specific genes) will need to be used. Direct evaluation of microbes in the distribution system (*Aeromonas*, *Mycobacteria*), ground waters (viruses), and surface waters (toxic algae) are now possible.
- *Waterborne Genomics:* More than 16 waterborne microorganisms have been or will be completely sequenced. Thus, the identification of the complete pathogen loading of virulence genes, resistance (persistence) genes, and potency genes could be made.
- *Rapid Assessment:* New instrumentation, such as biosensors that use liquid-core waveguides, will

be used in the future to identify the microbial contamination within 20 minutes and will have great application to beaches and ground waters as well as the problems that may occur in treatment plants.

We can meet the needs for protecting the water quality for the world's future through advancements in technology and monitoring. Billions of dollars will be spent on infrastructure and treatment in the future, rebuilding and improving water systems in the United States, and addressing the challenges of the world's water resources. Investing now in new microbial methods, which represent a small percentage of these costs, will better ensure our goal of safe water for all.

Thank you

I am so humbled and honored by this recognition of my contributions to water science and technology. I want to thank the Joan Irvine Smith & Athalie R. Clarke Foundation for supporting the Clarke Water Prize and for acknowledging the importance of water. I also want to thank the National Water Research Institute for establishing and faithfully administering the award and for making it one of the most important awards in water worldwide. I have been fortunate to have so many people who have helped me learn, overcome adversity, and contributed to the work that I am being honored for tonight. This award belongs to all of these people.

I want to thank my parents, Betty and Raymond Bray, for passing along their love of education; some special women in my formative years: Joan Carter and Elizabeth Messer; and my family (Tom, Rachel and Jared) for their companionship and support throughout our lives together, on all the sampling trips, and all the fun we've had. To my mentors (Martha Gilliam, Steve Taber, Martha Christensen, and especially Chuck Gerba) for showing me the passage to discovery. To my students, who have contributed the most to our work and continued to show me the excitement of water science. Finally, I want to thank all the dedicated professionals in the water industry and my friends in the academic world of public health water microbiology, who have taught me about and assisted me in understanding the importance of the work we do.

BIBLIOGRAPHY

Water Science and Technology Board, National Research Council, *Envisioning the Agenda for Water Resources Research in the Twenty-First Century*. 2001, National Academy Press, Washington, D.C.

Rose, J.B. and Grimes, D.J. 2001, *Reevaluation of Microbial Water Quality: Powerful New Tools for Detection and Risk Assessment*. American Academy of Microbiology, Washington, DC

Rose, J.B., Daeschner, S., Deasterling, D.R., Curriero, F.C., Lele, S. and Patz, J. 2000. Climate and waterborne disease outbreaks. *J. Amer. Water Works. Assoc*. 92:77-87.

LeChevallier, MW., M Abbaszdegan, AK Camper, G Izaguirre, M Stewart, D Naumovitz, M Mardhall, CR Sterling, P Payment, EW Rice, CJ Hurst, S Schaub, TR Slifko, JB Rose, HV Smith, and DB Smith. 1999. Committee Report: Emerging Pathogens: viruses, protozoa, and algal toxins. *J. Amer. Water Works Assoc*. 91(9):110-121.

Giardia cysts electron microscope graphic courtesy Metropolitan Water District of Southern California