



*“Nothing is more important
than the careful stewardship
and development
of our water resources.”*

– Athalie Richardson Irvine Clarke,

Summer 1991







The Athalie Richardson Irvine Clarke Prize

The Clarke Prize is presented annually for excellence in the fields of water science research and technology. It was established in 1993 by the National Water Research Institute to recognize individuals of exceptional ability, to promote better water research and technology, and to honor the vision of its co-founder, Athalie Richardson Irvine Clarke.

Mrs. Clarke, along with her daughter, Mrs. Joan Irvine Smith, provided the inspiration, encouragement, and financial support that established the National Water Research Institute. Mrs. Clarke's recognition of the vital importance of water science and technology, along with her dedication to excellence, is exemplified in all who are honored with The Clarke Prize. 





THE 2004
Clarke Prize Lecture & Award Ceremony

The St. Regis Monarch Beach Resort & Spa
Dana Point, California



Reception ~ 6:00 pm



Welcome ~ 7:00 pm

RONALD B. LINSKY

Executive Director, National Water Research Institute



Dinner ~ 7:15 pm



The Athalie Richardson Irvine Clarke Prize
SANDRA O. ARCHIBALD, PH.D.

Member, Clarke Prize Executive Committee



Presentation of the 2004 Clarke Prize

MRS. JOAN IRVINE SMITH

Co-Founder, National Water Research Institute



The 2004 Clarke Prize Lecture ~ 8:30 pm

VERNON L. SNOEYINK, PH.D.

Ivan Racheff Professor of Environmental Engineering

University of Illinois at Urbana-Champaign



Closing Remarks

JOHN B. WITHERS

Board Member, National Water Research Institute



THE 2004 CLARKE PRIZE
Executive Committee

Chair

DONALD R. F. HARLEMAN, PH.D.

*Ford Professor of Environmental Engineering, Emeritus
Massachusetts Institute of Technology*

SANDRA O. ARCHIBALD, PH.D.

*Dean and Professor, Evans School of Public Affairs
University of Washington*

MICHAEL C. KAVANAUGH, PH.D., P.E., DEE

*Vice President, National Science and Technology Leader
Malcolm Pirnie, Inc.*

JOAN B. ROSE, PH.D.

*Homer Nowlin Endowed Chair for Water Research
Michigan State University*

Vice Chair

JEROME B. WALKER, PH.D.

*Associate Provost
University of Southern California*

RAFAEL L. BRAS, SC.D.

*The Bacardi and Stockholm Water Foundations Professor
Massachusetts Institute of Technology*

BRUCE E. RITTMANN, PH.D.

*John Evans Professor of Environmental Engineering
Northwestern University*

ROY F. SPALDING, PH.D.

*Director, Water Center
University of Nebraska-Lincoln*



THE 2004 CLARKE PRIZE HONOREE

Vernon L. Snoeyink, Ph.D.

*Ivan Racheff Professor of Environmental Engineering
University of Illinois at Urbana-Champaign*

For over 35 years, Dr. Vernon Snoeyink has greatly influenced the way water engineers understand and solve water chemistry problems.

He is actively involved in drinking-water research, in the education of college students entering the water-quality profession, and in the development of solutions to global water-quality problems through his service on advisory boards, committees, and lectureships.

An environmental engineer, he has made groundbreaking contributions to the understanding, engineering, and teaching of processes that enhance drinking water.

The three research areas in which he has devoted his career include the control of corrosion products that form in drinking-water distribution systems; modeling the behavior of granular activated carbon to remove trace contaminants from drinking water; and innovative combinations of powdered activated carbon with membrane filters to enhance the performance of



membranes. His procedures are now widely used by major water utilities in the United States and Europe.

Dr. Snoeyink has been the Ivan Racheff Professor of Environmental Engineering at the University of Illinois at Urbana-Champaign since 1989, where he is known as an inspirational instructor who presents complicated information about drinking-water treatment in a simplified matter. More recently, he

became Director of the Science and Technology Center for Advanced Materials for the Purification of Water with Systems (Water CAMPWS) at the University of Illinois at Urbana-Champaign, which will be funded for 10 years by the National Science Foundation. In this position, he leads research programs at five partner universities to develop new materials and technologies for drinking-water treatment.

Dr. Snoeyink holds a B.S. in Civil Engineering, an M.S. in Sanitary Engineering, and a Ph.D. in Water Resources Engineering from the University of Michigan.



THE 2004 CLARKE LECTURE

Public Water Supply: Quantity, Quality, and Distribution Challenges

VERNON L. SNOEYINK, PH.D.

*Ivan Racheff Professor of Environmental Engineering
University of Illinois at Urbana-Champaign*

An adequate quantity of safe water is so important for everything that we do. Throughout the world, we are often faced with challenges caused by drought and population growth in water-short areas. In developing countries, the time and effort each household must expend to obtain a daily supply of water necessary to sustain life severely reduce productivity. Further, if the available water supply contains disease-causing microbes, the difficulty in obtaining water is compounded by a high incidence of debilitating disease that may lead to death. Providing an adequate supply of water to meet needs is one of the biggest challenges that face those involved in supplying water throughout the world. The challenge in



developing countries is to provide an adequate supply of water that is free from disease-causing contaminants. The potential for contaminating the water supply during distribution is a problem confronting the water-supply industry worldwide. Moreover, providing a supply at the point of use that is free not only from contaminants, but also from any suspicion of contaminants, is a special challenge in both developed and developing countries.

How Much Water Do We Need?

A major challenge confronting the water industry is to find ways to make the fixed quantity of water that we have serve our needs for centuries to come, given that there are serious problems with how freshwater is distributed throughout the world relative to the need



for freshwater. For example, on average, the United States has plenty of water: 10,000 cubic meters (m^3) per capita each year (or more than 7,200 gallons of water each day) of renewable water (Engelman and LeRoy, 1993), which is more than enough to meet our household, industrial, irrigation, and related needs. However, everyone in California and the Southwestern United States knows the problems that droughts cause, especially when considering the ecological needs of our surface waters. When demand is greater than the renewable supply, we sometimes create problems for future generations by depleting our groundwater aquifers and withdrawing too much water from surface-water bodies, thereby damaging their ecology.

It is informative for us to examine the quantity of renewable supply in other parts of the world.

Of interest are countries whose economic development is restricted to some degree by the renewable supply water (a level on the order of $1,700 m^3$ per capita each year [1,200 gallons per day]), and those with less than the amount required for an adequate quality of life in a moderately developed country (a level on the order of $1,000 m^3$ per capita each year [720 gallons per day]) (Engelman and LeRoy, 1993). Of course, these quantities are only general guidelines, because the actual impact of available

water depends very much on the way it is used. Since we often hear about the serious problems in the Middle East, it is of interest to examine the water availability there. Ten years ago, Israel had $463 m^3$ per capita available to her, while the Gaza Strip and West Bank had 166 and $128 m^3$ per capita, respectively (Engelman and LeRoy, 1993). According to Simon (1998), there must be agreement on water issues if the Middle East is to be stable, but the shortage of water will make agreement difficult.

The problem of water shortages will only worsen as populations grow. In 1990, 28 countries with populations totaling 335 million had less than $1,700 m^3$ per capita, and by 2025, 46 to 52 countries with 2.7 to 3.3 billion people will fall into this category (Figure 1).

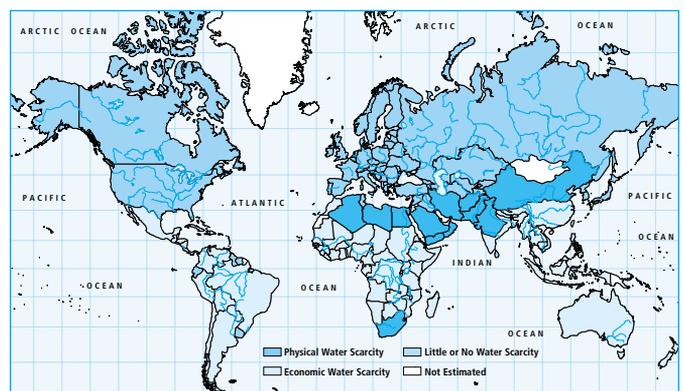


Figure 1. Projected water scarcity in 2025. Reproduced from Lantagne (2004).

In this figure, physical water scarcity corresponds to 1,000 m³ per capita-year and economic water scarcity corresponds to 1,700 m³ per capita-year. The importance of population is illustrated by a comparison of China and Canada. These countries have about the same amount of renewable water, but on a per capita basis, China has 2.2 percent of the amount in Canada (Engelman and LeRoy, 1993).

Localized problems related to water quantity are certainly close by. Figure 2 shows data from the United States Geological Survey for flows below all major dams and diversions on the Colorado River compared to the estimated flows if no dams and diversions structures had been built. It is apparent that no flow has reached the Colorado River delta in many recent years (Cohen, 2002).

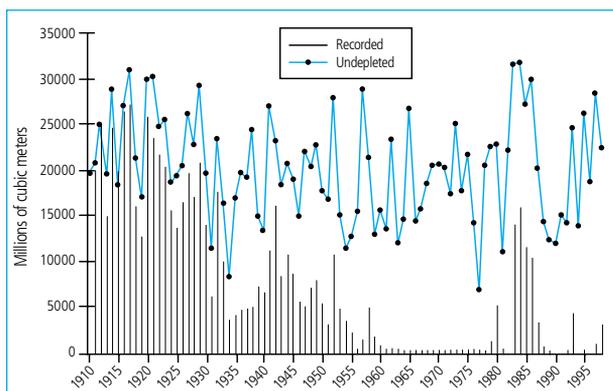


Figure 2. Annual flow in the lower reaches of the Colorado River. Undepleted flow refers to the flow that would have occurred had there been no upstream dams and diversions, and recorded flow refers to that at the entrance to the delta region. Reproduced from Cohen (2002).

Water rights were allocated without considering the in-stream flow needs of the delta, and it now appears that readjustments will have to be made to increase the flow into the delta and, thus, repair some of the damage that has been done to the delta’s ecosystem (Cohen, 2002).

Approaches to Meet Our Needs with the Available Renewable Supply

Gleick (2003) suggests that we are transitioning to a “soft path” approach to water management that complements the old approach of relying primarily on centralized physical infrastructure. The soft path involves smaller, lower cost community-scale systems that are decentralized, in addition to centralized infrastructure. The community is involved in decision making concerning water projects and policy, the use of equitable pricing, and the application of efficient technology and environmental protection. According to Gleick, this soft path looks not at water use as an end in itself, but to meeting the needs for household water, irrigation, manufacturing, etc. His opinion is that we can substantially reduce the quantity of water used for various purposes if we look at the need and the most cost-effective way to meet that need. For example, we may be able to use storm water, gray water, and reclaimed water for



landscapes and other non-potable applications (making good use of the decentralized waste treatment systems advocated by Dr. George Tchobanoglous in his 2003 Clarke Prize Lecture) and lifestyle changes will undoubtedly be necessary. Reclamation and reuse are important components of any plan to achieve water sustainability, and alternatives for the use of reclaimed water are shown in the hydrologic cycle diagram in Figure 3.

Singapore's Plan to Achieve Water Sustainability

Singapore is a good example of how water can be more efficiently used to develop a sustainable water supply. Lim et al. (2002) note that Singapore, a highly developed country, has a population of over 3 million on a 230-square mile island with a limited freshwater catchment area (Figure 4).

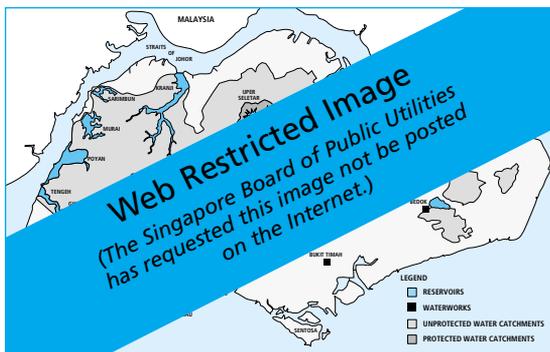


Figure 4. Singapore water-supply catchment areas. These catchments supply about one-half of Singapore's freshwater needs. Courtesy of Singapore Board of Public Utilities.

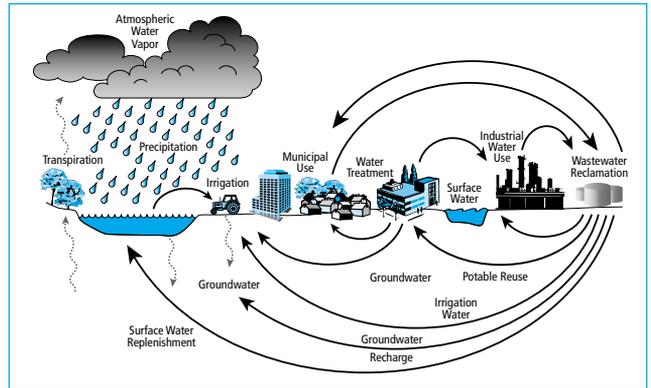


Figure 3. The hydrologic cycle, as modified by water reuse. Reproduced from Asano and Levine (1995a,b).

Fortunately, the mean annual rainfall in Singapore is 2.4 meters, but about one-half of this currently runs off to the ocean (Yang, 2003). Only about one-half of the country's current water needs is met using existing catchments, and the rest is obtained from neighboring countries. Singapore has embarked on a program to develop a sustainable water supply using sources inside the country, involving conservation, desalination, water reclamation, and the development of reservoirs in the ocean that can trap additional runoff for treatment in inland water treatment plants. Reverse osmosis desalination is expected to provide 30-million gallons of water per day by 2005 (Yang, 2003), but desalination is not looked upon as the answer to all their needs because this process is still relatively expensive. Hopefully, research and development, such as current efforts in California, will reduce the cost and make desalination a more viable option throughout the world.

Water reclamation is taking on increasing importance for Singapore. The NEWater program involves treating wastewater using biological processes, ultra-filtration, reverse osmosis, and ultraviolet disinfection. The operations building for the first 7-million



Figure 5. The NEWater Reclamation Plant at Bedok, Singapore. Courtesy of W.J. Ng.



Figure 6. The reverse osmosis system in the NEWater Pilot Plant at Bedok, Singapore.

gallons per day plant is shown in Figure 5, and the reverse osmosis system that is part of the pilot plant for this study is shown in Figure 6. The purpose of the NEWater project is to generate water that can be used by industry and can also be added to surface-water catchments and then be treated with other freshwater sources to produce potable supply.

The Challenge of Providing Safe Water in Developing Countries

Certainly, issues related to providing a sufficient quantity of water in developed countries are important, but a most important challenge facing water engineers and the developed world is the need to provide a sufficient quantity of safe water to

meet the basic human requirements of vast numbers of people in developing countries (Gleick, 2003). More than 1-billion people worldwide lack access to safe drinking water; several millions more drink unsafe water from improved sources (Lantagne, 2004), and 2.4 billion – more people than lived on the planet in 1940 – lack access to adequate sanitation services (Gleick, 2003). The failure to meet basic water needs leads to hundreds of millions of cases of water-related diseases and 2- to 5-million deaths annually (World Health Organization, 2000). It is interesting to note that in the early 1900s, diarrheal disease was one of the top 10 killers in the United States, and that it was eradicated by providing filtration, chlorine disinfection, and piped water distribution. Is the same approach the best alternative for developing countries? I believe this is an unanswered question.

If the current trend is allowed to continue, water-related deaths by 2020 are expected to be between 52 and 118 million deaths annually, mostly among children. Even if the United Nation's reaches its laudable target to reduce by half the number of people unable to reach or afford safe drinking water and adequate sanitation services by 2015 (Gleick, 2003), cumulative deaths by 2020 will be between 34 and 76 million (versus 68 million from AIDS). Money and assistance is required to achieve these goals and,



sadly, Gleick (2003) notes that from 1999 to 2001, the amount of money devoted to this problem actually declined. Many dedicated people in governmental and non-governmental organizations (NGOs) are working on this problem, and the beneficial impact of each one is important in terms of lives saved and the quality of life improved; these efforts must be strongly supported by us. There is a need to focus on simple, low-cost strategies to provide potable water first, and the development of systems to meet other needs should be a secondary priority.

Marion Medical Mission Shallow Well Program

The Marion Medical Mission Shallow Well Program is an effective NGO program serving rural areas in Malawi (Marion Medical Mission, 2004). Shallow dug wells are constructed adjacent to existing surface-water bodies. The wells are constructed by villagers with bricks made by villagers, and capped to protect well water from contamination; a hand pump is then installed to remove well water for use. Contaminants are removed via passage of the water through the ground to the well. Chlorination is not used because it cannot be reliably produced and distributed in this region. The cost for each well is about \$300, and it serves about 400 people. A maintenance person is trained to keep the well in working order, and the village pays 90 kilograms

of maize each year to the local hospital for all needed replacement parts. Narrow-mouth capped vessels are used to transport and store the water, and education on the need for cleanliness is provided. The hospital administrator has reported substantial reductions in dysentery in communities that use the wells. The system appears sustainable because local teams are trained to construct the wells and to install and manufacture the pumps.

A Federal organization that has an effective program in place is the Center for Disease Control (CDC) in Atlanta, Georgia, and I will describe it in detail because it helps to frame the problem facing us.

CDC Safe Water System

The CDC Safe Water System is a point-of-use system that is technologically quite simple and has achieved excellent success (Lantagne, 2004). It involves collecting water in a narrow-mouth, lidded vessel with a spigot, and treating the water with a capful of dilute chlorine bleach per 20 liters for at least 30 minutes before use (Figure 7).



Figure 7. Chlorine bleach and a narrow-mouth storage bottle with a spigot are key components of the CDC Safe Water System. Courtesy of Lantagne (2004).

The vessel is especially important because it enables water collection, transportation, disinfection, and storage, and the water can be dispensed from it without recontamination. The chlorine can be produced locally, an important criterion for any treatment material that is to be used in a sustainable system, although the need to distribute it after production could be a serious disadvantage, especially in rural areas. These two items were marketed together as part of the first national Safe Water System project in Bolivia in 1996.

In addition to the chlorine and vessel, critical components of the system are the messages and methods used to induce people to buy and use the system, and to make healthy changes in behavior, such as safe water handling and improved hygiene and sanitation (Lantagne, 2004). Printed materials (as well as messages that are broadcast on radio and TV), community mobilization campaigns, and interpersonal behavior change techniques (such as motivational interviewing) are used. Cost is very important relative to acceptance and continued use. Fortunately, the bleach solution only costs 10 to 25 cents per month for a family, and the storage vessel costs between \$2 and \$5, so the Safe Water System is fairly cheap.

The CDC has found that the Safe Water System consistently reduces diarrhea by about 50 percent

in countries such as Bolivia, Zambia, Kenya, Madagascar, and Pakistan, and that a major factor related to success is personal hygiene, such as handwashing. Data from the World Health Organization on hand washing indicates that even developed countries have room for improvement in this area (Table 1).

Country	Hand Washing with Soap after Toilet (%)	Mother Hand Washing with Soap after Cleaning Up Child (%)
Kyrgyzstan	18	0
Burkina Faso	1	13
Lucknow	46	21
United Kingdom	30 to 75	47

Source: World Health Organization (2001)/London School of Hygiene and Tropical Medicine (unpublished)

The CDC System now affects about 5-million users, and by 2007, it is proposed that the coverage will be expanded to 100-million people (Figure 8). These are large, impressive numbers, but when compared to the global burden of 1.1-billion people served by unsafe water, we see that we have much work left to do.

Reasons for the success of the CDC Safe Water System appear to be the involvement of people from the community being served and working partnerships with NGOs that have effective operations in



the community. Getting the appropriate messages out and continuous follow-through to ensure that the System is being properly used are essential for success (Lantagne, 2004).

Solar Disinfection

Many other methods and processes, such as drilled wells, shallow dug wells with hand pumps, specially designed filters, and porous ceramic pots, are being employed in small communities in developing countries to excellent advantage. One of the simplest and most effective approaches is the solar disinfection process called Sodis (World Health Organization, 2000). It was pioneered in Lebanon in the 1980s, and it uses the sun, throwaway plastic soft drink bottles, and a black surface. The bottles are filled with water and placed horizontally on the flat black surface (Figure 9) for about 5 hours. The ultraviolet light, combined with the temperature increase because of light absorption by the black surface, appear to effectively kill bacteria, although there is some question about

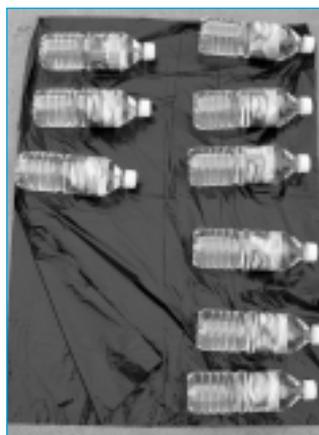


Figure 9. The disinfection process Sodis involves disinfection in transparent plastic bottles using ultraviolet light from sunlight absorption to increase the water temperature.

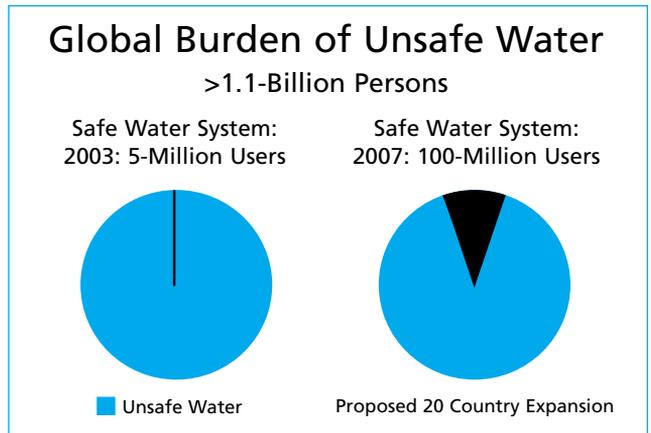


Figure 8. The impact of the CDC Safe Water System on the global burden of unsafe water: 2003 versus the proposed expansion by 2007. Courtesy of Lantagne (2004).

whether it kills viruses and protozoa cysts such as *Giardia lamblia* and *Cryptosporidium parvum*. Lantagne (2004) estimates the cost of using it

as \$1 per family per year, but notes that it does have the disadvantage of not working in bad weather, and that it requires supervision from someone who understands the process. The process is limited because it does not change water properties such as turbidity, taste, odor, or concentrations of organic and inorganic contaminants, and it may not kill pathogens that are protected by particles.

Developing Country Research Needs

One of my activities at the University of Illinois is to direct the National Science Foundation's Science and Technology Center for Advanced Materials for Purification of Water with Systems (Water CAMPWS), which involves researchers from Clark Atlanta University, Stanford University, the University of California, Berkeley, Ohio State University, and Rose Hulman Institute of Technology, in addition to the University of Illinois. One of our goals is to conduct research that has an impact on the water-quality problem in developing countries. We have some ideas for improving the durability and effectiveness of the low-cost, porous ceramic pot that is widely used in homes in many countries to filter out particles and microorganisms. Also, we are working with nickel-impregnated titanium dioxide that uses natural light to generate hydroxyl free radicals, and we believe there is good potential to use this material to more effectively disinfect water. We also would like to investigate low-cost, low-pressure membranes that might have application for the types of problems that are encountered. From the point of view of education, we also would like to develop research and education relationships with universities in developing countries, and provide online courses for them to use in their educational programs. It is our intent to develop

materials and systems that will be useful to NGOs and governmental organizations in meeting the variety of water needs that exist.

Water Distribution and Storage Systems

Once purified, water in both developing and developed countries requires good distribution and storage systems if it is to be free from disease-causing organisms. Figures 10 and 11 show distribution and storage systems that are common in developing countries.

Imagine that safe water from a community well was put in the pot that the woman is carrying. Contact with her hands during transport could easily contaminate this water, creating the likelihood that it will cause disease if it is not disinfected before use. This is one of the reasons why it is so important to improve personal hygiene at the same time that drinking-water quality is being improved, as well as to use closed vessels



Figure 10. A water distribution system in a developing country, with the potential for contamination during transport. Photo courtesy www.kamat.com.



Figure 11. Water storage in developing countries. Photo courtesy USAID.



for transport and storage, if the incidence of diarrhea is to be substantially reduced.

Contamination during storage in open vessels at the point of use is also possible. Figure 12 shows water transport by truck to an open barrel; the water would definitely require disinfection after delivery because of the possibility of contamination during transport and storage.

Bottled water (Figure 13) is a common means of distributing water in the peri-urban areas of large cities. Meeting the water supply and sanitation requirements of these areas is one of the greatest needs in developing countries since these areas are often not served by safe water supplies. Entrepreneurial street vendors then become water suppliers. Unfortunately, the bottles they use may not have been cleaned before use, and may have been filled using an unsafe source. Costs for such water are usually excessive, and can range from \$0.20 to \$6.00



per person per day. Certainly, effective regulation is sorely needed (Lantagne, 2004).

Figure 13. Bottled water is another form of water distribution, especially in peri-urban areas that are not served with an improved supply. A green tint is visual evidence that the water might not be of good quality. Courtesy of Lantagne (2004).



Figure 12. Water distribution in a developing country. Disinfection after delivery is advisable. Courtesy of Lantagne (2004).

The distribution of water also represents a major challenge for us in developed countries. After treating water to a high quality in a central facility, the possibility of contamination during distribution is a real possibility unless the water is properly treated for transport and the distribution system materials are properly controlled. Deterioration of our distribution systems, both those under the control of water utilities and in our places of residence, are critical issues. The corrosion of water pipes causes water-quality deterioration, increased energy to transport water, and loss of water, and the replacement costs for pipes in our municipal systems are estimated at hundreds of billions of dollars over the next two decades (Edwards, 2003). Many of our cities have unlined cast iron pipes that look like the photos in Figures 14 and 15.



Figure 14. Unlined cast iron pipe from the Cincinnati, Ohio, network.

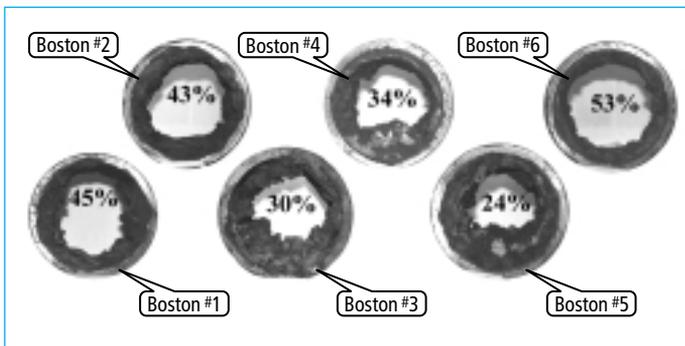


Figure 15. Metropolitan Water Resources Authority (Massachusetts) unlined cast iron pipe, which is approximately 100 years old. The percentages show the amount of cross-sectional area available for water flow.

If water quality and flow conditions in these pipes are not properly controlled, they can cause the formation of iron particles that appear at the tap in the form of colored water, causing clothes and fixtures to be stained and other aesthetic problems. It should be emphasized that both of the cities referred to in these figures supply tap water that meets all drinking-water

standards. Finding the money to replace these pipes is a most important need facing our cities.

When water quality at the tap is compromised, consumers lose confidence in the quality of the tap water. This is indeed unfortunate for an industry that prides itself in providing safe water at the tap, and does so with only rare exception. Unfortunately, when public notification is required to inform the consumer that excessive coliform have been found in the distribution system and that water must be boiled before consumption, or that excessively high levels of lead have been measured in tap water, public confidence in the water supply is severely shaken. When the aesthetic quality is poor and the water does not look, taste, or smell right, consumers suspect that the water is unsafe. As consumer confidence is lost, their use of point-of-use treatment devices and bottled water increases, and the water utility may not be able to regain their confidence after the problem is corrected. We in the water industry have the ability to control these problems much better than we now do, and we need to put the time, effort, and money into doing so.



Concluding Remarks

The water-supply industry faces important challenges in supplying the quantity of water that is needed throughout the world, in supplying safe water to residents of developing countries, and in ensuring that water delivered to the point of use not only does not become contaminated during transport, but also is free of any suspicion of contamination. The increasing population in water-short areas makes our job particularly difficult, and meeting these challenges in developing countries – given the unique constraints encountered – is especially daunting. The nature of the problems varies widely, from those associated with dense populations in peri-urban areas to those of small populations spread out in rural areas. Solutions that are tailored to meet the needs of each type of problem are needed, and the amount of funding, from both governmental organizations and concerned individuals, needs to be substantially increased. Certainly, we have our work cut out for us, but as all of us who work in the profession know, the personal satisfaction of making a difference is very great.

Acknowledgements

An occasion such as this makes me reflect on the past and on the many positive influences of individuals that have been, and are, so important in shaping

my career and in being such an important part of my life. First and foremost is my family: my wife Jeannie, whose love and support have been so important to me; our son Todd, his wife Shana, and their daughter Eve, as well as our son Craig, his wife Marah, and their son Jacob, who are such an important dimension of my life; my parents, Ben and Anna Snoeyink, now deceased, who would have enjoyed this event so much; my brothers and sisters who could not be here today; Jeannie's father Martin (deceased) and mother Anna, who is here with us tonight and who is celebrating her ninetieth birthday this year; and Jeannie's brothers and sisters, many of whom are here tonight.

Then there are University of Michigan professors: Eugene Glysson, who in 1958 advised me, a young high school graduate with no plans for further education, to go to college; and Walter J. Weber, Jr., 1996 Clarke Prize Laureate, who convinced me that the chemistry of drinking-water treatment processes would make a great research career and guided me when I was getting started. I also thank my colleagues at the University of Illinois who have made that university such a great place to teach and do research, the same colleagues who in the early days of my career taught me what it meant to be a professional, who have been advisors and friends



throughout my career, and who have added so much to all of my research efforts by collaborating with me.

I have been truly blessed with professional colleagues outside the University of Illinois who taught me so much through our casual research-related conversations, and whose friendship has made being in this profession so enjoyable.

The best part of my professional career has been the opportunity to work with students, to be part of their lives in some small way, and to reap the significant benefits from interacting with them: with the undergraduates, who continually challenged me to teach relevant topics; with the masters students, whose time in the laboratory with me was short, but whose research

accomplishments were important and whose career achievements are so enjoyable to observe; and with the Ph.D. students (Jain, Paul, Paul, Makram, Byung, Michael, John, Bob, Bill, Wayne, Abraham, Evangelos, Lina Su, Issam, Shaoying, Samer, Fred, Detlef, Jennifer, Mark, Tom, Carlos, Con, Mary Jo, Jess, Qilin, Pankaj, Darren, Lance, Priscilla, Li, and George) who were, and still are, such an important part of my life, and who made their greatest achievements when they ignored some of my suggestions and instead pursued their own research ideas.

Finally, I would like to thank Mrs. Athalie Richardson Irvine Clarke, Mrs. Joan Irvine Smith, and the National Water Research Institute for this tremendous award.





References

- Asano, T., and A.D. Levine (1995a). "Wastewater Reuse: A Valuable Link in Water Resources Management." *Water Quality International*, No. 4: 20-24.
- Asano, T., and A.D. Levine (1995b). "Wastewater Reuse: A Valuable Link for Water Resources Management." *Water Quality International*, No. 12: 18-22.
- Asano, T., and A.D. Levine (1996). "Water Reclamation, Recycling and Reuse: Past, Present, and Future," *Water Science and Technology*, vol.33, no.10-11, pp. 1-14.
- Cohen, M. (2002). "Managing Across Boundaries: The Case of the Colorado River Delta." *The World's Water 2002-2003*, P. Gleick, Island Press, Washington, DC.
- Edwards, M. (2003). "Water Distribution System Corrosion: One of the Grand Engineering Challenges for the 21st Century." *Proceedings of the First IWA Conference on Scaling and corrosion in Water and Wastewater Systems*, 25-27 March 2003, Cranfield University, Bedfordshire, United Kingdom.
- Engelman, R., and P. LeRoy (1993). *Sustaining Water, Population and the Future of Renewable Water Supplies*, Population Action International, Washington, DC.
- Gleick, P.H. (2003). "Global Freshwater Resources: Soft-Path Solutions for the 21st Century." *Science*, 302: 1,524.
- Lantagne, D. (2004). "Safe Water Supply Options in the Developing World: Point-of-Use to Large-Scale Infrastructure Solutions." University of Illinois seminar held April 8, 2004.
- Lim, J., W.J. Ng, K.L. Chew, and V. Kalianpur (2002). "A Model for Decentralised Grey Wastewater Treatment System in Singapore Public Housing." *Water Science and Technology*, 46(9): 63.
- Marion Medical Mission (2004).
Website: <http://marionmedical.org/water.htm>.
- Simon, P. (1998). *Tapped Out*, Welcome Rain Publishers, New York.
- World Health Organization (2000). *Global Water Supply and Sanitation Assessment 2000 Report*, World Health Organization, Geneva.
- World Health Organization (2001). *Water for Health*, World Health Organization, Geneva.
- Yang, S.-Q. (2003). "Potential Water Resources in Singapore." *AQUA*, 52(6): 425.





THE CLARKE PRIZE

Laureates



1994 Recipient: BRUCE E. RITTMANN, PH.D.

For the past 20 years, Dr. Rittmann has built a such an impressive body of research that, at present, he is among the most highly respected researchers in the field of water quality. His methods for cleaning up contaminated drinking water, wastewater, and groundwater, as well as his specialization in the biodegradation of common water contaminants, have earned him numerous honors.

Dr. Rittmann's strong commitment to the advancement of water research is indicated by his extensive involvement with numerous organizations, such as serving as former Chair of the National Research Council's Committee on *In Situ* Bioremediation and as former President of the American Association of Environmental Engineering Professors. Currently, he is the John Evans Professor of Environmental Engineering at Northwestern University in Evanston, Illinois.

1995 Recipient: DAVID C. WHITE, M.D., PH.D.

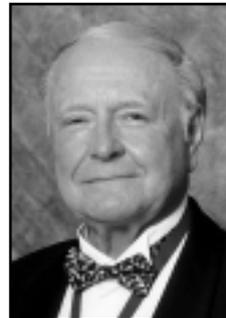
Dr. White revolutionized the practice of environmental microbiology. His groundbreaking approaches and methods for studying microorganisms in their natural environments opened up the possibility of applying cutting edge analytical technology to microbial ecology. He has applied his expertise to many areas, including deep subsurface microbiology, sewage microbiota, marine sediment communities in polar and temperate regions, and waterborne pathogens.



One of Dr. White's greatest assets is his willingness to collaborate with other applied and environmental microbiologists, often spending more time helping others with their research than on his own projects. He currently is a Distinguished Professor in the Department of Microbiology, University of Tennessee-Knoxville, and Director of the Center for Biomarker Analysis.

1996 Recipient: WALTER J. WEBER, JR., PH.D., P.E., D.E.E.

Dr. Weber is recognized internationally for his seminal work on the development of advanced technologies for water treatment and concepts for ensuring potable water sustainability. He founded the Environmental and Water Resources Program and the Institute for Environmental Sciences, Engineering, and Technology at the University of Michigan, as well as the Great Lakes and Mid-Atlantic Hazardous Substance Research Center and the National Center for Integrated Bioremediation Research and Development.



Over the past 40 years, Dr. Weber has authored or co-authored four books and over 300 peer-reviewed technical and scientific papers, and has mentored over 70 Ph.D. graduates. Among his honors, he was named a Diplomate in the American Academy of Environmental Engineers in 1975 and elected to the National Academy of Engineering in 1985. Currently, he is the Gordon M. Fair and Earnest Boyce Distinguished University Professor at the University of Michigan at Ann Arbor.



1997 Recipient: PERRY L. MCCARTY, Sc.D.

Dr. McCarty is universally recognized for his research directed towards understanding of contaminant behavior in groundwater aquifers and sediments. He has also made significant contributions to environmental engineering and science through research in water treatment and reclamation, groundwater recharge, and water chemistry and microbiology. He has been published over 300 times and is co-author of the textbooks, *Chemistry for Environmental Engineering and Science*, and *Environmental Biotechnology – Principles and Application*.

Currently the Silas H. Palmer Professor of Civil and Environmental Engineering Emeritus at Stanford University, Dr. McCarty was the first Director of the Western Region Hazardous Substance Research Center. His honors include election to the National Academy of Engineering and as Fellow in the American Academy of Arts and Sciences, American Academy of Microbiology, and American Association for the Advancement of Science. He is an honorary member of the American Water Works Association and the Water Environment Federation. In 1992, he received the John and Alice Tyler Prize for Environmental Achievement.



1998 Recipient: RAFAEL L. BRAS, Sc.D.

Dr. Rafael Bras is one of the leading hydrologists in the world. One of his greatest innovations was uniting hydrology with probability and statistics to improve forecasting and risk estimation. His rainfall and spatially distributed runoff models have significantly advanced river-flow forecasting and flood estimation. Other areas of groundbreaking research include monitoring network design, landscape evolution and geomorphology, and the impact of deforestation on local and regional climate, among others. Dr. Bras has written two hydrology textbooks and has published over 130 journal papers.

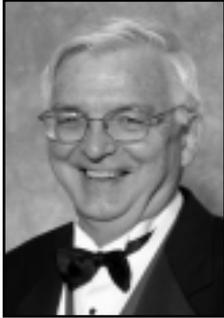
At the Massachusetts Institute of Technology (MIT), Dr. Bras is the Bacardi and Stockholm Water Foundations Professor and Chair of the MIT Faculty, and is the former head of the Civil Engineering and Environmental Department. He is a member of the National Academy of Engineering and a corresponding member of the National Academy of Engineering in Mexico, as well as a Fellow of the American Geophysical Union, the American Meteorological Society, and the American Society of Civil Engineers. Dr. Bras holds an honorary degree from the University of Perugia in Italy and was recently elected to the Hispanics Hall of Fame in the United States.

1999 Recipient: JAMES J. MORGAN, Ph.D.

With a career that has spanned over 35 years, Dr. Morgan has been deemed to be the “master guru of aquatic chemistry” by his peers. He has been described as a gifted pioneer within his field, a captivating classroom teacher, and a leader among men. Among his many awards, he was honored with the 1999 Stockholm Water Prize, presented by King Carl XVI Gustaf of Sweden. At present, Dr. Morgan is the Marvin L. Goldberger Professor of Environmental Engineering at the California Institute of Technology (Caltech) in Pasadena, California.



Dr. Morgan’s research achievements have led to the development of improved technologies for the treatment of wastewater and drinking water. He had also made fundamental contributions in several areas, including groundbreaking discoveries regarding acid rain in Southern California, as well as the transport of heavy metals and contaminants in ocean and coastal waters. In addition, he has authored over 100 peer-reviewed technical publications and co-authored the pivotal textbook, *Aquatic Chemistry*.



2000 Recipient: CHARLES R. O'MELIA, PH.D.

For over four decades, Dr. O'Melia has made substantial contributions to the basic understanding of physical and chemical processes for water treatment and the behavior of particles in the natural water environment. He is widely acknowledged as one of the most outstanding water-quality engineers in the area of filtration and coagulation processes in engineered (water treatment plants) and natural (lakes and estuaries) systems.

In the field of environmental science, Dr. O'Melia is known for his intellectual leadership, as well as the highest personal standards in research, scholarship, and education. He has advised more than two dozen doctoral students and has authored over 100 technical publications, including *Watershed Management for Potable Water Supply: Assessing the New York Strategy* (2000). His work has earned him numerous honors and awards, including membership to the National Academy of Engineering. Currently, Dr. O'Melia is the Abel Wolman Professor of Environmental Engineering at The Johns Hopkins University in Baltimore, Maryland.

2001 Recipient: JOAN B. ROSE, PH.D.

For more than 20 years, Dr. 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 microorganism *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. Currently, Dr. Rose is the Homer Nowlin Endowed Chair for Water Research at Michigan State University.



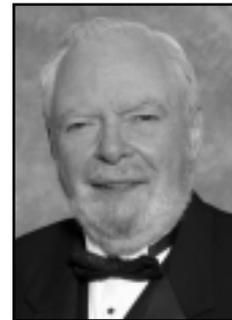
2002 Recipient: HARRY F. RIDGWAY, PH.D.

For 25 years, Dr. Ridgway has pioneered significant studies on membrane technology, particularly the discovery of the crucial role that microorganisms play in influencing the structure, function, and effectiveness of membrane materials used in purifying water and wastewater (the process is known as biofouling). He has also developed new methodologies to observe, measure, and quantify bacterial attachment to membranes under controlled conditions in the laboratory.

Because of his many accomplishments, nearly every membrane manufacturer in the world has worked directly with Dr. Ridgway to test and reformulate their newest and most advanced membrane materials to reduce the effects of biofouling. In addition, today's membrane processes are much more efficient and less costly due to research and developments made possible by his work. At present, Dr. Ridgway is President of his own company, AquaMem Consultants, in Las Cruces, New Mexico.

2003 Recipient: GEORGE TCHOBANOGLOUS, PH.D., PE

For over 30 years, wastewater expert Dr. Tchobanoglous taught courses on water and wastewater treatment and solid waste management at the University of California, Davis, where he is Professor Emeritus in the Department of Civil and Environmental Engineering. He is widely recognized for advancing the use of new technologies in four key areas: constructed wetlands for wastewater treatment, the application of alternative filtration technologies, ultraviolet disinfection for wastewater reuse applications, and decentralized wastewater management.



Dr. Tchobanoglous has authored or coauthored over 350 publications, including 12 textbooks and three reference books. The textbooks have been used at more than 225 colleges and universities in the United States. Notably, the textbook, *Wastewater Engineering: Treatment, Disposal, Reuse*, now in its fourth edition, is one of the most widely read textbooks in the environmental engineering field by both students and practicing engineers. Currently, Dr. Tchobanoglous serves as a national and international consultant to both government agencies and private concerns.



NATIONAL WATER RESEARCH INSTITUTE

Creating New Sources of Water Through Research and Technology and Protecting the Freshwater and Marine Environments

Since its establishment in 1991, the National Water Research Institute has become a leading force in building strategic joint venture partnerships to enhance funding for water research. Known as the “institute without walls,” the National Water Research Institute does not carry out research itself, but operates with the clear intent of facilitating, coordinating, and supporting deserving research projects wherever outstanding people and facilities are found throughout the world.

The Joan Irvine Smith and Athalie R. Clarke Foundation has contributed over \$15 million, which has been ambitiously matched by the National Water Research Institute’s partners, such as federal and state governments, private industry, public utilities, and universities, to support over 160 projects in the past 13 years. These investments have supported specific projects focusing on exploratory research, treatment and monitoring, water quality assessment, and knowledge management. The National Water Research Institute also develops partnerships internationally. Australia, Canada, The Sultanate of Oman, and The People’s Republic of China are among these strategic global partners. 