The 2003 Clarke Prize Honoree

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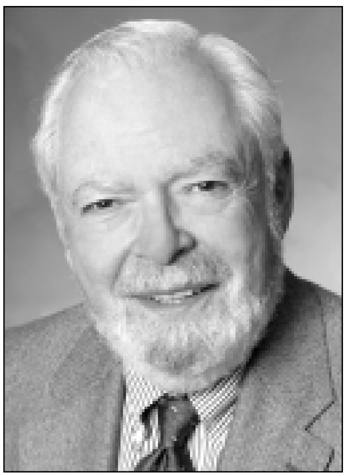

Wastewater expert Dr. George Tchobanoglous has made significant contributions to the practice of environmental engineering through his research, publications, public service, and international activities. He is widely recognized for advancing the use of new technologies in four key areas: constructed wetlands for wastewater treatment, the application of alternative filtration technologies, ultraviolet (UV) disinfection for wastewater reuse applications, and decentralized wastewater management.

Dr. Tchobanoglous' early work on the use of wetlands for wastewater treatment culminated in the first national conference on the subject in 1979. Based on his filtration research, a variety of new filtration technologies have been approved for use in California in restrictive reclamation applications. His successful studies on UV radiation have brought about the widespread acceptance of UV disinfection in water reuse applications. As Chair of NWRI's UV committee, he helped draft the first UV guidelines for water reuse in 1993. Recognized as an expert on decentralized wastewater management systems, he has been asked to be a keynote speaker at more than 15 conferences in the past 3 years.

Perhaps Dr. Tchobanoglous' greatest impact has been in the training of environmental engineers. He is the author or coauthor of 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, as well as at universities worldwide, both in English and in translation. His books are famous for successfully bridging the gap between academia and the day-to-day world of the engineer. Notably, his 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.

The 2003 Clarke Lecture

The Importance of Decentralized Wastewater Management in the Twenty-First Century

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Previous winners of the Athalie Richardson Irvine Clarke Prize have written eloquently about a broad range of water-quality and environmental issues. The subject of my discussion is decentralized wastewater management (DWM). Given the important role that DWM can play in the protection of public health and the environment and in the management of water resources, this subject has not received the attention it deserves or requires. I hope, through the opportunities made possible by the Clarke Prize, to promote the critical role of DWM in protecting public health and the environment, and to promote long-term water sustainability in the twenty-first century.

DWM may be defined as the collection, treatment, and reuse/dispersal of wastewater from individual homes, clusters of homes, isolated communities, industries, or institutional facilities at or near the point of waste generation. To put the subject of DWM in perspective, it is useful to think about the following issues:

- The *need* for and *importance* of DWM.
- *Opportunities* for water reuse and their potential impact on sustainability.
- The status of DWM *technologies* for wastewater treatment and reuse.
- New *management* strategies that must be developed.
- *Challenges* that must be faced and overcome in implementing DWM systems.

The Need for DWM

The need for DWM systems can be established by reviewing three key areas:

- The population now served — and the need for future populations to be served — with DWM systems.
- The need to develop a more sustainable approach to the management of water resources.
- The limited reuse opportunities and dilution capacity available for effluent disposal at centralized facilities.

Figure 1. View of Stinson Beach, California, a coastal community served entirely with individual onsite systems.

Current and Future Populations Served with DWM Systems

With the passage of the Clean Water Act in the early 1970s, it was reasoned that it was only a matter of time before sewerage facilities would be available to almost all residents of the continental United States. Now, more than 30 years later, it is recognized that the complete sewerage of the United States may never be possible due to geographic and economic constraints. At present, more than 60-million people in the United States live in homes where individual decentralized systems (most typically comprised of a septic tank and leachfield) are used for wastewater management (Figure 1). Many of the existing systems need to be upgraded and all should be managed. While most DWM systems used in the past required only periodic maintenance, they rarely received any. Because design standards varied so widely, many DWM systems have been designed and constructed inappropriately. In some instances, there was no design at all. For these and various other reasons, numerous onsite system failures have occurred along with groundwater contamination. Clearly, effective DWM systems are needed for the protection of public health and the environment. The United States Environmental Protection Agency now estimates that about 33 percent of the new homes being built are served with onsite systems. As new systems are implemented, it is important that they be designed, constructed, operated, and managed in a manner that will protect public health and the environment.

A More Sustainable Approach to Water Resources Management

In the United States and in many other parts of the world, the orderly development of urban and urban fringe areas depends on the availability of water. In areas where available sources of water are limited or are unreliable, it is now recognized that wastewater represents a very reliable water source. If wastewater from urban and urban fringe areas were reused locally for a variety of nonpotable uses, the demand on the potable supply would be reduced. Local reuse, in conjunction with other interventions such as conservation, can help achieve sustainable water use and reduce the need for infrastructure expansion. Thus, the focus of wastewater management must begin shifting from the construction and management of regional sewerage systems to the construction and management of decentralized wastewater treatment facilities.

If localized water reuse is to gain acceptance, effective DWM systems must be used to create a paradigm shift from effluent disposal ("wastewater is a problem") to water reuse ("wastewater is a resource").

Limited Reuse Opportunities and Dilution Capacity

Historically, wastewater treatment plants were located in remote areas, typically near rivers or the ocean. In the intervening years, the area surrounding most wastewater treatment plants has developed to the extent that the localized reuse of large quantities of treated effluent at or near the treatment plant site is often no longer feasible. Unfortunately, building new pipelines to transport treated wastewater to locations where it can be reused beneficially has proven to be prohibitively expensive. Concurrently, in many locations, the available dilution capacity in the receiving water body is no longer sufficient to meet the needs of future growth. In these locations, DWM systems can be used effectively to bring about localized reuse and to reduce the quantity of wastewater discharged to centralized wastewater treatment facilities.

Local Reuse Opportunities

The utilization of water from local sources will depend on available reuse opportunities and their corresponding water-quality requirements.

Reuse Opportunities

Worldwide, the most common use of reclaimed wastewater has been for agricultural and landscape irrigation. Other reuse opportunities include industrial uses, groundwater recharge, recreational/environmental, nonpotable urban uses (Figure 2), and indirect potable use. For the short-term, landscape irrigation will continue to be the principal reuse option for individual decentralized systems in urban areas.

In many metropolitan areas, building codes for new commercial and industrial facilities now require the installation of dual plumbing. Reclaimed water for toilet flushing in these facilities would be provided most economically by treatment facilities located within the building complex (the practice in Tokyo, Japan) or nearby. Wastewater to be treated would be mined (extracted) from the wastewater collection system. To maximize the reuse of larger quantities of treated wastewater at or near the point of generation, the use of satellite reclamation plants connected to collection systems for sludge processing (as in Los Angeles County, California, for their upstream reclamation plants) will continue to increase in the future.

In isolated commercial and industrial facilities, toilet flushing in buildings with dual-plumbing systems, landscape irrigation, and water used for water features will continue.

Water-Quality Requirements

Treatment requirements for reuse are evolving as our understanding of public health and the environmental risks associated with reuse is being quantified. With respect to the required treatment processes, concerns for newly emerging pathogenic organisms that may arise from nonhuman reservoirs (e.g., the protozoan parasites *Cryptosporidium parvum* and *Giardia lamblia*) has led to the questioning of the use of traditional indicators that arise primarily from fecal inputs. To protect public health and the environment and to maximize reuse opportunities, water-quality requirements

Figure 2. Typical example of a water feature using reclaimed water. Mirror pond at the Japanese Garden at the Donald C. Tillman Reclamation Plant in Los Angeles, California.

for treated wastewater for small dischargers are now the same as those for large dischargers. Because new organisms are being found routinely, reuse standards will continue to evolve and, in turn, appropriate treatment technologies must be developed.

Technologies for Decentralized Systems

One of the impediments to the development of DWM is the perception that the technologies available for individual onsite systems are inferior to those available for centralized facilities. While the lack of technologies may have been true in the past, significant changes have occurred within the last 10 years. Great strides have been made in understanding the fundamentals governing the processes involved in treating wastewater and in developing new equipment and technologies (Crites and Tchobanoglous, 1998). Some of these technologies and new approaches are discussed below for individual decentralized systems, metropolitan areas, and isolated commercial facilities.

Technologies for Individual Decentralized Systems

Historically, individual onsite wastewater management systems, which evolved from the pit privy, were comprised of a septic tank and a gravity-fed, gravel-filled trench called a leachfield or drainfield (also known as soil absorption systems) for the disposal of the effluent from the septic tank. Because the effluent from the septic tank was applied to the leachfields by gravity, leachfields had to be located below the outlet of the septic tank. Partial treatment of the organic matter (biochemical oxygen demand [BOD]) and solid material (total suspended solids [TSS]) in wastewater occurs through sedimentation and anaerobic decomposition in the septic tank. Effluent from the septic tank is treated further within the biological mat that develops at the soil interface within the gravel-filled leachfield trench and as it travels through the soil. While use of the soil for treating BOD and TSS was acceptable in the past, it is not appropriate for the twenty-first century, given all of the other constituents now found in septic tank effluent (e.g., pharmaceutically active substances, cleaning agents). The extensive and valuable treatment capacity of the soil should be used for treating these new constituents, as well as nitrogen and phosphorus, and not for BOD and TSS (which can be treated easily in a variety of treatment units). Important developments for individual systems have occurred in all aspects of DWM, including: pretreatment, treatment, reuse/dispersal, and monitoring. Some of these developments are further discussed.

Wastewater Pretreatment: The most noteworthy advance in pretreatment is the development and use of effluent filters to eliminate the discharge of large untreated solids and to modify particle-size distribution in the effluent discharged from septic tanks. In addition to significant improvements in the quality of the effluent, it is now possible to use small high-head (e.g., 300-foot) multi-stage water-well turbine pumps to pump septic tank effluent. These pumps are used for pressure sewers, dosing of treatment processes, and pressure dosing of reuse systems and leachfields at different locations and elevations. Attached growth units that maximize the rate of decomposition of organic wastes within the septic tank are under development both here and abroad.

Wastewater Treatment: Using current technologies, it is possible to produce any required effluent water quality. In a recent study for the California State Water Resources Control Board (Leverenz et al., 2002), more than 200 vendors were identified for individual onsite wastewater treatment technologies. While the cost may be high with some of the technologies identified, developments are proceeding at such a rapid pace that it is fair to say that treatment costs associated with DWM systems will be more than competitive with centralized facilities, especially when the cost of wastewater collection is considered. Common treatment systems include packed-bed reactors, biological treatment units, and constructed wetlands. The textile filter (Figure 3), a recent development that employs a synthetic filter medium, has reduced the size of home treatment units significantly (20-square feet versus 400-square feet for an intermittent sand filter). The use of constructed wetlands is especially popular in

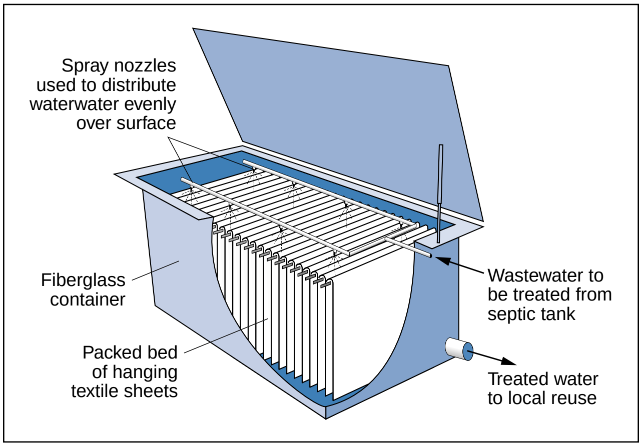

Figure 3. Schematic of textile filter for the treatment of septic tank effluent.

England and Europe. A typical system employing advanced technologies in a home equipped with dual plumbing (separate plumbing for toilets and clothes washing facilities) is shown in Figure 4. As shown, the amount of potable water entering the home is reduced because of effluent treatment and recycled. Depending on the technologies

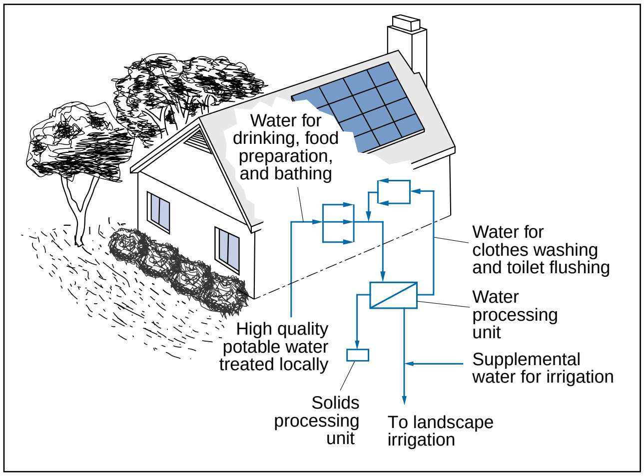

Figure 4. The home of the future with dual plumbing.

used, additional water may be required for yard watering. In the situation illustrated in Figure 4, the key question is not whether such a technology will be developed, but rather, how such technologies should be managed.

Effluent Reuse/Dispersal: At the beginning of the last century, the shallow leachfield trenches used for the disposal of septic tank effluent were dug by hand; however, with the passage of time and as mechanical excavation equipment became available, leachfields tended to become deeper. Although deep leachfields can function hydraulically, it is recognized that their use has, in a number of cases, led to the contamination of groundwater. Unfortunately, most past designs failed to take maximum advantage of the treatment capabilities of soil, because the point of discharge in the leachfield trench is typically located below the region of maximum bacterial activity in the upper 12 inches of the soil horizon. To utilize the treatment capacity of the upper soil horizon, treated effluent must be dispersed over the widest possible area. Such dispersal can be accomplished by means of drip irrigation or by using a shallow pressure-dosed gravelless absorption chamber, as shown in Figure 5. It is interesting to note that the use of shallow trenches was recommended in an early Public Health Bulletin (Lumsden et al., 1915) to maximize the beneficial use of the constituents in wastewater (Figure 6).

Monitoring: To improve the management of existing and new onsite systems, monitoring will be required. Low-cost programmable logic controllers and monitoring devices are now available for controlling pumping, treatment,

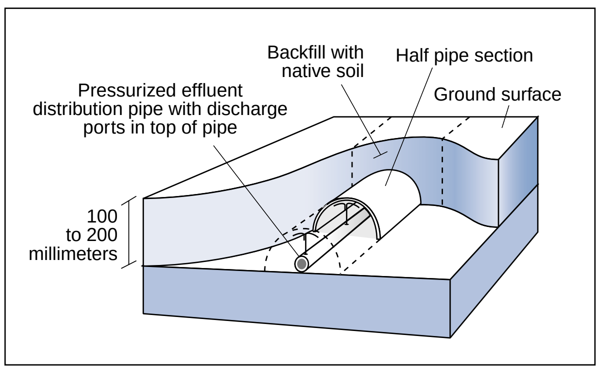

Figure 5. Shallow gravelless pressure dosed adsorption field.

dispersal functions. With the availability of low-cost monitoring devices and a variety of telecommunication options, it is now possible to monitor the operation of many hundreds of onsite systems from any internet access location. Given that such monitoring devices exist, two key questions arise that must be answered:

- How can monitoring devices best be used to manage DWM systems?
- What should be done with all of the information that will become available?

Technologies for Metropolitan Areas

Another relatively recent development, the membrane biological reactor (MBR), consists of a biological reactor (bioreactor) in which micro-filtration membranes are used to separate treated water from the suspended biomass (Figure 7). Treated water is withdrawn from the bioreactor by vacuum, and excess biological solids — produced during treatment — are discharged to the collection system for processing downstream. Because membrane systems produce an effluent quality equal to the combination of secondary clarification and effluent microfiltration, they are now being used in a number of DWM applications to produce water for toilet and urinal flushing in new buildings with dual-plumbing systems and for park and greenbelt watering within metropolitan areas. In Melbourne, Australia, which is currently experiencing a drought, complete portable packaged MBR treatment units have been used to produce water for the irrigation of parks and greenbelts. Worldwide, as new water supply sources become increasingly difficult and costly to develop, the use of MBRs will become more common in the future.

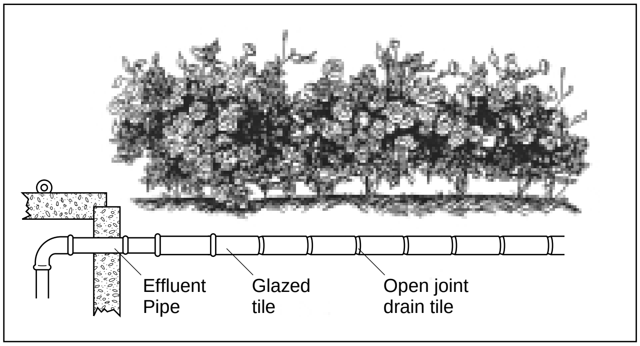

Figure 6. Distribution of effluent from a privy into top soil (after Lumsden et al., 1915).

Technologies for Isolated Commercial Facilities

In the past 20 years, a number of self-contained recycling technologies were developed to collect wastewater from buildings, treat it, and return the bulk of the treated effluent for reuse as toilet and urinal flushing water, landscape irrigation, and

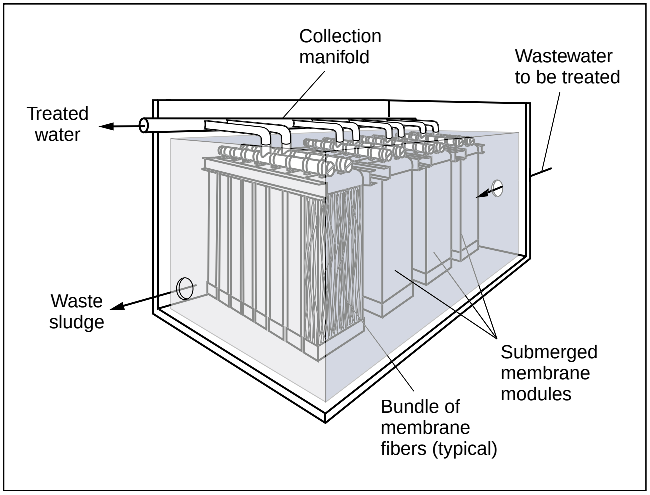

Figure 7. Schematic of a membrane bioreactor for the treatment of wastewater.

other water features. Typically, such systems have involved some form of biological treatment followed by microfiltration and/or reverse osmosis and disinfection. Although self-contained recycle processes are expensive, they have been used for office buildings located in unsewered areas and where water for domestic use is in short supply.

Management Strategies for DWM Systems

Considering the many new and untested technologies that continue to be developed for DWM applications, as well as the past problems that have plagued onsite systems, it is clear that new DWM systems should be allowed only if a responsible management agency has been designated prior to their design and construction. The unanswered question is what type of management structure should be used. New management structures must be developed to encompass both centralized and decentralized wastewater management systems. Flexible management arrangements have to be developed to deal with the many different types of DWM systems that will be proposed. The challenge is to find the most suitable combination of management options for each situation. Recognizing the importance of management, the United States Environmental Protection Agency has developed a draft guidance manual for DWM systems (United States Environmental Protection Agency, 2003).

Challenges for DWM in the Twenty-First Century

To reach their full potential in the twenty-first century, in the context of water reuse and water resources management, DWM systems must — in addition to protecting public health and the environment — help create a paradigm shift from effluent disposal to water reuse, help overcome outdated rules and regulations, and be integrated with centralized facilities.

A Paradigm Shift from Effluent Disposal to Water Reuse

If localized water reuse is to gain acceptance, effective DWM systems must be used to create a paradigm shift from effluent disposal ("wastewater is a problem") to water reuse ("wastewater is a resource"). To accomplish this shift, DWM systems must meet rigorous performance requirements and be operationally reliable (i.e., robust). With the technologies now available and with proper monitoring and maintenance, the poor performance of the past can be overcome successfully. To achieve equal status with centralized treatment, effective performance standards, application criteria, and management strategies must be developed for DWM components and systems.

If wastewater from urban and urban fringe areas were reused locally for a variety of nonpotable uses, the demand on the potable supply would be reduced.

Outdated Rules and Regulations

To implement the new technologies now available for DWM systems, it is necessary to overcome the inconsistencies between scientific advancements and existing rules and regulations governing DWM systems. Many of the existing standards and regulatory requirements for DWM systems are based on past experience or developed on an *ad hoc* anecdotal basis with limited and, in some cases, poor science. As a result, there are many inconsistencies between current research (applied and fundamental) findings and regulations. Clearly, these issues must be resolved to achieve widespread public acceptance of water reuse with DWM systems.

Integration of DWM Systems with Existing Centralized Systems

As urban and suburban sprawl continues, there will be many opportunities for integrating DWM systems with existing centralized systems. A continuum of possibilities are imaginable that will change the role of existing facilities, result in more efficient treatment processes, and better recognize the value of water. The types and form of the integration will depend on the layout of the existing collection system and projected growth patterns.

Closing Thoughts

Effective DWM systems are needed for existing and future populations served with such systems, for the sustainable management of water resources, and to reduce the impact of increasingly large wastewater discharges on receiving water bodies. With the advances made in the technologies currently available for use in DWM systems, it is now possible to produce an effluent water of any desired quality. The challenge in the twenty-first century is to develop effective management systems that will protect public health and the environment, maximize reuse, and allow for the integration of DWM systems with other centralized facilities in the development of water resources management plans.

Thank You

With thanks and appreciation to Mrs. Joan Irvine Smith and the National Water Research Institute for establishing the Clarke Prize, in honor of Athalie Richardson Irvine Clarke, to promote the value of water in our lives. I am honored to be the tenth recipient of this most prestigious award. Space does not permit me to thank all of the colleagues and friends who have made this award possible, but I would like to single out some pivotal individuals. First and foremost, my wife Rosemary, who has been my steadfast friend, supporter, and editor for more than 46 years. My daughters, Kathryn, Lynn, and Julianne, who have provided moral support and cheered us on. My parents, who came to the United States from Greece, would have been so proud of this honor.

I could not have reached this point without the support and encouragement of Rosemary's parents, Dr. Donald and Rosemary Ash.

Three of my professors were also important mentors. Vern Harrison at the University of the Pacific, Erman Pearson at the University of California at Berkeley, and Rolf Eliassen, my Ph.D. advisor at Stanford University. I am grateful for the contributions that each of these individuals made to my education. Takashi Asano, Ray Krone, Jerry Orlob, and Edward Schroeder, my colleagues at the University of California at Davis, have helped my career in innumerable ways. Max Burchett, my dear friend, has helped me understand the practice of environmental engineering. My thanks also to my book coauthors and friends, Frank Burton, Ronald Crites, Frank Kreith, Howard Peavey, Robert Sanks, Edward Schroeder, David Stensel, Hilary Theisen, and Sam Vigil. My thanks also to the many engineers I have had the privilege of working with in my career. Finally, I want to thank my many students who helped to educate me and have made my teaching career most rewarding and worthwhile.

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The Joan Irvine Smith and Athalie R. Clarke Foundation has contributed over $13.7 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 135 projects in the past 12 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.