1999 Clarke Lecture

Health of the Waters and Water for Health

James J. Morgan, Ph.D.
Marvin L. Goldberger Professor of Environmental Engineering Science
California Institute of Technology
Pasadena, California

I THANK YOU FOR THIS GREAT HONOR. This is an occasion for celebration, for expressing gratitude, and for reflection on the importance of water for our lives and the life of the earth. We celebrate and express our appreciation for the leadership of Athalie Richardson Irvine Clarke and her daughter, Mrs. Joan Irvine Smith, in bringing the National Water Research Institute into being at the beginning of this decade. The Institute established the Clarke Prize 6 years ago to honor the founding vision of Mrs. Clarke in support of water resources.

As the most recent person selected to receive the Clarke Prize, I feel privileged to be welcomed into the distinguished company of Drs. Bruce Rittmann, David White, Walter Weber, Perry McCarty, and Rafael Bras, all of whom share an interest in, and a sense of responsibility for, the development and the protection of the water environment. Each of us brings our own perspective to the science and technology of water. Mine is that of aquatic chemistry, through which we attempt to understand chemical processes in natural waters which govern their composition, both in aquatic ecosystems and in engineered systems.

Natural waters are complex, and their chemical behavior can only be understood in conjunction with essential knowledge provided by other sciences, for example hydrology, atmospheric science, biology, geology, and ecology. This recognition of the interdependence of chemistry and other disciplines in studying the water environment was pioneered more than 30 years ago by my "doctor father" at Harvard University, Werner Stumm. His death a scant 3 months ago has evoked in his many students and colleagues a sense of great loss. I think of his teaching and mentoring early in my research career as a great gift from a great individual. His sense of concern for the water environment throughout his life and his infectious enthusiasm for scientific understanding of natural waters will surely live on. On this special day in my life, I celebrate his memory and express profound gratitude for all that he gave to us in improving water science and technology.

"All the rivers run into the sea; yet the sea is not full."

– Ecclesiastes 1:7

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.

Rivers played an important part in my early life, long before I was introduced to their engineering analysis in my first environmental course at Manhattan College in 1952. And, the Atlantic Ocean and the crossing of it was crucial for my Irish immigrant parents and their two children. My father crossed the Atlantic by ship five times, my mother three times, myself twice, and my younger sister once (Perhaps those early sea-going days assured that I would never want to become an oceanographer!). I have a keen sense of gratitude for the courage and determination of my parents in making America our home. As to the rivers, some were great, some small.

1999

I was born within hailing distance of the Hudson River (although I have no recollection of being hailed by anyone). Then, soon back in Ireland for 4 years, the brook running near the edge of our farm was a favorite place of mine. I loved the flow of the water and visiting with fishermen neighbors.

"Nothing is so gentle, so adaptable as water,
yet it can wear away that
which is hardest and strongest."

– Lao-tzu, 6th century B.C.

When the family settled in New York City for good, my world was, for years, bounded by the Hudson and Harlem Rivers. Indeed, the Public School 189 song contained the unforgettable line, "Enshrined between two rivers bright, our schoolhouse nobly lies"! Perhaps caught up in enthusiasm for the "bright" Hudson, ca. 1946, I actually swam in it on one occasion, and lived to tell of it. I even caught a fearsome looking catfish with a broomstick, a bent nail, and a worm; my catch was not met with joy by Mother, who did not let it past the front door. Thus ended my young, brilliant career as an urban swimmer-fisherman.

As an undergraduate civil engineering student at Manhattan College in the early-1950s, I first learned about the water environment from Professor Donald O'Connor, a brilliant and dedicated teacher of fluid mechanics, river oxygen dynamics, and treatment processes. His exciting introduction to environmental engineering set me on a course that has been very like a river in its own way, with the living flow and eddies and meanders of a stream.

Pursuing a master's degree at the University of Michigan, I was recruited to work with Professor Velz, whose forte was the application of oxygen profile analysis to establishing design objectives of wastewater treatment plants along rivers. My acquaintance with rivers widened as I worked out in the field, in the laboratory, and made computations for studies of streams such as the Kalamazoo, the Clinton, and the Miami. I studied hydrology, hydraulics, microbiology, additional mathematics and statistics, and engineering design. Precious little chemistry that did not concern dissolved oxygen rarely entered my mind.

In 1956, I joined the staff in Civil Engineering at the University of Illinois, where my "life on the river" soon took a distinctly chemical turn. At that time, problems of stream pollution by synthetic detergents and algal nutrient phosphate were becoming recognized. It became important to know whether these chemicals could interfere with efficiencies of water treatment plants on rivers. My river experience grew to include the Mississippi, the Kaskaskia, the Illinois, and the Sangamon. For the first time in my young life as a civil engineer, chemistry became of interest to me. It turned out to be both consequential and challenging for understanding chemical pollution and the treatment of the affected waters. I soon learned that water chemistry had already been found both practical and challenging by others during the preceding 50 years! Chemists, among them, A.M. Buswell, E. Bartow, A.P. Black, W.F. Langelier, T.E. Larson, J.C. Morris, and Werner Stumm — recently arrived at Harvard University from Switzerland in 1956 — had been investigating natural water chemistry, particularly in the context of treatment processes and corrosion control. T.E. Larson, a distinguished chemist then heading up water quality at the Illinois State Water Survey in Champaign (just three blocks from my Civil Engineering quarters), was very kind in offering me a key piece of advice in 1959, upon my telling him that chemical behavior of rivers and groundwaters had now become important to me to understand: Go East young man, and study with Stumm at Harvard. I did. It changed my life. I started the process of becoming what a senior colleague I much admire likes to call me now: "An engineer gone wrong."

With Werner Stumm, I learned about the chemistry of coagulation and particle removal rates in water, the laws describing transformations of manganese in natural waters, and the central importance of particle surfaces in water for the success of many different processes both under natural environmental conditions and in engineered treatment processes.

"All praise be yours, my Lord,
through Sister Water,
So useful, humble, precious and pure."

– Frances of Assissi, 12th century A.D.

a água aqua dwr el agua hydor H_2O l'acqua l'eau maa maimm maji
mool pani shui uisce vári vatten Vand voda das Wasser water Woda

It became my goal to choose experiments that might provide more general chemical understanding of the complexity of the world of natural waters, and that could also be applied to treatment processes. And, inspired by the papers of the Swedish physical chemist, Lars Gunnar Sillén, on the reasons underlying composition of seawater, Werner Stumm and I became interested in how equilibrium models might be applied to rivers, lakes, groundwaters, and treatment processes in order to better understand their chemical behavior.

"Beside the rivering waters of, hitherandthithering waters of."

– James Joyce, 1939

So, 36 years ago, when I departed Harvard for a faculty post in water chemistry at the University of Florida, I envisioned a career in which basic questions about particles and surfaces, rates of reactions in water, and better understanding of actual chemical forms of key elements in water — what we now call "speciation" — would occupy me for some time. And indeed, they have continued to be lively and challenging for me and my student colleagues to this day. At Florida, I had the privilege of working side by side with Dr. A.P. Black, one of the giants of water treatment chemistry. He introduced me to the study of polymers as water treatment agents, and he welcomed me to join him in advising graduate students studying coagulation and flocculation in water.

A last word on rivers: two more tested my resolve along the way — "twin estuaries," the Fennhalloway and the Waccasassa, on the Gulf Coast of Florida, one polluted, the other pristine. Doubtless, you have all heard of the "real world." After sampling and modeling for a year and a half, the hurricane of 1964 sent everything in both rivers well out to the Gulf of Mexico. That was my "real world." I made a decision soon thereafter. Field work on a great scale was probably not for me. And, I made a second decision, or rather the California Institute of Technology (Caltech) made it for me, through the leadership of Professor Jack McKee, founding father of environmental engineering at Caltech. The Institute offered me a faculty job, and Jack assured me that basic water chemical research studies in the lab according to my stated vision was just what Caltech had in mind (although work in the field was certainly not prohibited!). I joined the Caltech faculty in 1965 and have worked there happily ever since.

It has been my great pleasure and good fortune to teach and advise students of Caltech for many years. I have been able to advise and co-advise over 30 Ph.D. student colleagues. Often, I worked jointly with faculty colleagues Wheeler North, Jack McKee, John List, and Norman Brooks in guiding research that was truly multidisciplinary. Together, my student and faculty colleagues believe that we have come to a better understanding of the complex world of natural waters and that we have offered new chemical approaches to treatment processes. My students and postdocs have devised some useful new "tools" for aquatic chemistry (e.g., computer programs and methods of chemical analysis). We have proposed some new "stories" (i.e., explanations or models for how processes work "out there" in nature). Our goal in aquatic chemistry and environmental engineering science is to better explain and predict the workings of rivers, lakes, groundwaters, and treatment processes. We have, of course, needed to simplify nature's complexity to move forward, but heeding the dictum of Albert Einstein: "Everything should be made as simple as possible, but not simpler." Whatever I have achieved, it could not have come about without the partnership of my student, postdoctoral, and faculty colleagues.

Why have I titled these remarks *Health of Waters and Water for Health?* Because there are two faces to the challenge of future water development: The need for water supplies that will safeguard human health and advance human welfare, and the need to preserve aquatic ecosystems and the larger local, regional, and global ecosystems of which they are a part. In my experience with the water environment and for the environmental ethic I believe in, the natural world and appropriate technology need to be jointly supported by our science. Our motivation should be harmony with the environment, not "mastery." In this way, we may aspire to achieve *Health of the Waters and Water for Health.*

"Water…
'the blood of the universe.'"

– Kuo Hsi, 11th century A.D.

"If you don't have water, you don't have life, so we need to take care of the water. We do not own the water. The Great Spirit does. We have the responsibility to treat water with respect."

– Floyd Standing Warrior, Lakota Tribe, Engineer,1999