The Periodical of the American Academy of Environmental Engineers® Fall 2009

ENVIRONMENTAL *Engineer*

Debra Reinhart, Ph.D., P.E., BCEE

The Landfill Lady

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The Quarterly Periodical of
The American Academy of Environmental Engineers®

www.aaee.net

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Environmental Engineer is published by the American Academy of Environmental Engineers®. Address all communications on editorial, business and other matters to:

Editor-in-Chief,
Environmental Engineer®
American Academy of Environmental Engineers®
130 Holiday Court, Suite 100
Annapolis, Maryland 21401
410-266-3311

PUBLISHER
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1-866-985-9782 • FAX 1-866-985-9799
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Design/layout: Stacia Harrison
Advertising Coordinator: Lauren Campbell

Craig Kelman & Associates

ENVIRONMENTAL *Engineer*

Fall 2009 | Volume 45, Number 4

FEATURES

Environmental Engineer: Applied Research and Practice

DEPARTMENTS

by Debra R. Reinhart, Ph.D., P.E., BCEE

Environmental Engineering Grand Challenges

I am amazed by how fast this year went by! Thank you for the honor of serving as your President.

This has been a productive year and AAEE is growing stronger through your collective efforts. We have 128 applicants this year and our total membership is 2461. We recently modified our bylaws to better serve our membership, we have initiated a new Sustainability Certification, Joe Cavarretta completed his first year as our Executive Director and initiated many new programs to streamline our operations, we have new Tau Chi Alpha chapters, the *Environmental Engineering Body of Knowledge* was published, and the Air and Waste Management Association has rejoined AAEE as a sponsoring organization.

In July, I attended the Association of Environmental Engineering and Science Professors' (AEESP) biannual conference entitled "Grand Challenges in Environmental Engineering and Science: Research and Education." The presentations reinforced the fact that environmental engineers are front and center in the response to many global challenges we hear and read about on an almost daily basis. A listing of AEESP conference session titles clearly describes some of these challenges: managing the nitrogen cycle, water sustainability, environmental economics, carbon capture and storage, and nanotechnology.

There is much that the AAEE community can do to help meet the grand environmental engineering challenges.

I was also impressed with the new tools that are available to deal with these grand challenges. Molecular methods now allow us to identify pathogens historically undetectable and can be used in risk assessment and policy making. We now have better life cycle analysis tools that promote consideration of resource consumption and pollutant emissions as well as cost. Microscopic and spectroscopic instruments are used to manipulate and examine materials at nanoscale, leading to the discovery of new materials that will dramatically change our lifestyles while helping to evaluate the safety of these new products. I read in *Science,* this week, about the use of data recently gathered by GRACE satellites that suggest significant groundwater depletion rates in a 2000-kilometer area across the Indian subcontinent; findings that exceeded previous estimates by 70%.

Expanding populations and global economies place increasing pressure on natural resources. The consequences of these demands are evident throughout the world.

- Nearly one billion people lack safe potable water sources.
- Over one billion people are without access to proper sanitation.
- Carbon dioxide emissions increase globally 2.5% per year; the emissions from developing regions doubled between 1990 and 2006.
- An area the size of Bangladesh is deforested each year.
- We see the impact of global resource demand in declining fish populations, flooding, contaminant presence in natural waters and blood samples, and in the emergence of antibiotic-resistant organisms.

There is much that the AAEE community can do to help meet the grand environmental engineering challenges. A few that occur to me include:

- get involved in public policy making,
- learn more about the history of our profession,
- consistently include other disciplines in project teams,
- volunteer to teach and mentor K-12 and university students,
- work to increase funding for basic and applied research needed to meet these challenges,
- consider sustainability and life cycle implications in every design or operation in which we are involved,
- volunteer or give to charities such as Water For People or Engineers Without Borders, and
- look for innovative ways to meet multiple societal needs such as using wastewater to grow algae for biofuels.

Again, thank you for your support and confidence. I wish all the best to our new president, Cecil Lue-Hing, in the coming year. EE

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New Specialty Offered

The AAEE is pleased to announce a new certification: Environmental Sustainability.

This new certification emphasizes the application of sustainability principles to the everyday practice of environmental engineering. It covers general principles and applications to water/wastewater, solid and hazardous waste, air, energy, and development.

Whether you are a current member who wishes to be certified in an additional specialty or someone who is applying for AAEE certification for the first time, you are encouraged to submit your application. Applications received by March 31, 2010, will be in the inaugural examination cycle for this new and exciting certification.

Specialty Certification Renewal

The 2010 Specialty Certification Renewal packages were sent in September. We cannot stress enough the importance of completing and returning your renewal with payment as soon as possible. Each year, many members miss the opportunity to be listed in *Who's Who in Environmental Engineering®* because they did not submit their Specialty Certification Renewal and Member Data Form before the deadline.

2010 E3 Competition

The deadline for the 2010 E3 Competition is February 1, 2010. Winning entries will be announced at the AAEE Awards Luncheon on April 28, 2010, at the National Press Club in Washington, D.C., and are automatically eligible for entry into the International Water Association Project Innovation Awards (PIA).

Entering its 21st year, the Excellence in Environmental Engineering® Competition is organized around the normal phases of development and implementation of environmental management projects and programs: research, planning, design, and operations and management.

Those chosen for prizes address the broad range of modern challenges inherent in providing life-nurturing services for humans and protection of the environment. Their innovations and performance illustrate the essential role of environmental engineers in ensuring a healthy planet. These award winners testify to the genius of humankind and best exemplify the Excellence in Environmental Engineering® criteria.

Visit the AAEE website for guidelines, submission forms, and profiles of previous award winners. Get the national and international recognition you deserve!

Environmental Engineer: Applied Research and Practice

Included in this issue is the ninth volume of *Environmental Engineer: Applied Research and Practice*.

Since being introduced in the Winter 2007 edition of *Environmental Engineer®, Applied Research and Practice* has published fourteen peer-reviewed papers on a variety of topics.

The Editorial Board of *Environmental Engineer®* invites you to submit your journal paper to be published in an upcoming issue. Because of quality review, prompt turnaround, a targeted audience, and ease of submission, papers to *Environmental Engineer: Applied Research and Practice* are generally published within two to four months of receipt. Submittal instructions are on page 22.

Upcoming Events

AAEE has had an active year by sponsoring and participating in a number of meetings, conferences, seminars, and workshops around the country. By the time you get this issue of *Environmental Engineer®*, AAEE will have just returned from Orlando, Florida, where AAEE held its Annual Board of Trustees meeting, exhibited at WEFTEC'09, and held the WEF/AIDIS/AAEE Breakfast. Other events still on AAEE's agenda for 2009 include:

- **November 4, 2009 - Washington, DC**
  AAEE Workshop Lunch, Training Center, Metropolitan Washington Council of Governments. Time: 12:00 noon to 2:30 p.m. Fee: $35; "Chesapeake Bay, Progress to Date/Future Efforts"; Dr. Rich Batuik, Chief Scientist for EPA on the Chesapeake Bay; Dr. Clifford W. Randall, Ph.D., C.P. Lunsford Professor Emeritus, Civil and Environmental Engineering, Virginia Polytechnic Institute and State University. To register, visit www.aaee.net.
- **November 8-13, 2009**
  AIChE Annual Meeting, Gaylord Opryland Hotel, Nashville, TN
  AAEE/AIChE Breakfast: "Sixty Years of Biological Wastewater Treatment", W. Wesley Eckenfelder, Jr., D. Sc., P.E., DEE; Wednesday, November 11; Cost: $28. Time and Room TBD. **EE**

DID YOU KNOW?

1973 AAEE President Frank R. Bowerman (1922-1998) served as Technical Consultant for MGM studios' 1973 science fiction movie, *Soylent Green* starring Charlton Heston, Leigh Taylor-Young, Chuck Connors, and Edward G. Robinson. At that time, Mr. Bowerman was Professor and Director of Environmental Engineering Programs at University of Southern California. *Soylent Green,* based on Nebula Awarding winning novelist Harry Harrison's *Make Room! Make Room!* takes place in a futuristic and overpopulated New York.

by Joseph S. Cavarretta, CAE

Update on Academy Activities

As the Earth rotates 1,000 mph and orbits at 67,000 mph, it reminds me of how fast we're heading into the end of the year. Here's a brief update on some of AAEE's current activities:

Campaign 4000

The Campaign 4000 program is gaining momentum. AAEE received three contributions since making a plea for support last quarter in *Environmental Engineer*®. That knocks down the number of donors needed from 114 to only 111. The Academy personally recognizes and sincerely thanks those who have made the commitment. Some supporters have made two contributions or more of $1,000. Once again, AAEE only needs 111 more commitments of $1,000 to reach its goal. The commitment may be made in "three easy payments" of $333.33 per year. If you are considering donating to Campaign 4000, please do it soon, as 2009 represents the third and final year of the original program. Donations may be included on renewal forms and via the Campaign 4000 form on page 9.

Wanted: 320 New Applicants for 2010

Now is the time to identify and encourage worthy candidates to apply for certification. With strength in numbers, the Academy is better able to make the case for formal recognition of its certification by government agencies large and small. At nearly 2,500 members, AAEE represents less than 5% of all eligible environmental engineers. As stated in the 2008 Fall Issue of *Environmental Engineer®*,"...we not only have an opportunity to grow but also a duty to grow ...to help agencies and organizations obtain the expertise they will need ...[to meet] ...the unique challenges of tomorrow." AAEE encourages and supports your efforts to advocate for more applicants within your organization. Would you like some help? Please feel free to contact us: 410.266.3311; email: jcava@aaee.net.

Building Awareness and Educational Opportunities

AAEE and its certification programs are becoming increasingly recognized, thanks largely to committed volunteers who are building Workshops and Seminars and to its Sponsoring Organizations and their BOT liaisons in the form of exhibits and presentations. Equally important is the positive impact on the environmental engineering community of the educational opportunities that AAEE now offers.

In October, AAEE is again exhibiting and co-hosting its annual WEF/AIDIS/AAEE breakfast at WEFTEC, Orlando, Florida, in conjunction with AAEE's Annual BOT Meeting October 14-15. Keynote Speaker is James L. Barnard, Ph.D., Pr. Eng., BCEE, the 2007 recipient of WEF's annual Athalie Richardson Irvine Clarke Prize for excellence in water research.

Upcoming events include AAEE's first-ever Workshop Lunch in Washington, DC, from 12:00 p.m. to 2:30 p.m. November 4, 2009, at the Metropolitan Washington Council of Governments. The focus is the Chesapeake Bay. Speakers include Chief Scientist for EPA on the Chesapeake Bay Dr. Rich Batuik; and Dr. Clifford W. Randall, Ph.D., C.P. Lunsford Professor Emeritus, Civil and Environmental Engineering, Virginia Polytechnic Institute and State University. AAEE is proud to be exhibiting for the first time at AIChE's Annual Conference, November 8-13, at Opryland Hotel, Nashville, Tennessee, and honored to be co-hosting with AIChE a first-ever breakfast Wednesday, November 11, featuring W. Wesley Eckenfelder, Jr., D.Sc., P.E., DEE. The topic is "Sixty Years of Biological Wastewater Treatment."

New Database

AAEE began migrating to a 21st century database in early summer. Once in place, members will be able to log into their own page and update their information, renew certification electronically, access a detailed membership directory similar to the print version (a less detailed version will be available to the public), access information about their specific involvement in AAEE activities, and much more.

Website

A taskforce of AAEE volunteers has been working on a project to renovate the Website. Their short-term goal is to create a plan that may be readily adopted to improve and refine online resources, interaction, and navigation. They have discussed many exciting developments that will please members and visitors alike. Currently, members and visitors may now search the AAEE Website by scrolling to the Google Search at bottom of the home page. To search AAEE.net, simply click on the appropriate button and enter your search terms.

As always, AAEE values and encourages your questions and comments. Please email jcava@aaee.net. EE

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People on the Move

Jeffrey M. Harris, P.E., BCEE, has joined the Houston, Texas, office of SCS Engineers. His career in the engineering practice extends to over 30 years with accomplishments that include holding a U.S. patent for a Facultative Landfill Reactor, wetlands mitigation, performance of design calculations for surface water management in Hong Kong, and preparation of permit drawings and supporting documentation for landfills in Malaysia and New Zealand. Mr. Harris has been board certified in Solid Waste Management since 1988.

Awards & Honors

Davis L. Ford, Ph.D., P.E., BCEE, was selected by the WEF Board of Trustees as the 2009 recipient of the Industrial Water Quality Lifetime Achievement Award. Dr. Ford, of Davis L. Ford & Associates in Austin, Texas, will receive this distinguished award at WEFTEC'09. He has been board certified in Water Supply and Wastewater Engineering since 1975 and is a Past President of AAEE.

Frank D. Hutchinson P.E., BCEE, was presented the Distinguished Service Award by NCEES for his dedicated service to the engineering and surveying profession. His service record includes helping to develop the first Environmental PE Exam and being a member of the NCEES Environmental exam development committee, where he has served as chair for the past 10 years. Mr. Hutchinson has been board certified in Solid Waste Management since 1996.

Stephen C. Lane, P.E., BCEE, has been re-elected as National Director of the American Council of Engineering Companies of Tennessee. Mr. Lane is Executive Vice President of Smith Seckman Reid, Inc. and has been board certified in Water Supply and Wastewater Engineering since 1989.

In Memoriam

Francis W. "Monty" Montanari, passed away on June 25, 2009 at the age of 92. Mr. Montanari was well known for his commitment to bringing safe water and sanitary services to people all over the world and was instrumental in the development of AWWA's non-profit organization, Water For People. He had been board certified in Sanitary Engineering since 1958.

Russell L. Poling, Jr. P.E., BCEE, passed away in April 2009. Mr. Poling had been board certified in Water Supply and Wastewater Engineering since 1991.

Roque A. Roman Seda, Ph.D., P.E., BCEE, passed away in June 2009. Dr. Roman Seda had been board certified in Water Supply and Wastewater Engineering since 1987.

Alfred H. Samborn, P.E., BCEE, passed away on March 19, 2009. Mr. Samborn was a Retired Professor of Civil Engineering at the University of Toledo and one of the founders of SSOE. He had been board certified in Solid Waste Management since 1977.

AWWA-NJ's Run For Water

The New Jersey section of the American Water Works Association held their inaugural "Run For Water" on July 25, 2009. The 5K and 1/2 Mile Fun Run was held to benefit Water For People, a non-profit organization that raises money to benefit developing countries by providing clean drinking water, adequate sanitation, and hygiene education to regions in Latin America, Africa, and Asia.

The first annual 5K and 1/2 Mile Fun Run was held at the Historic Monmouth Battlefield State Park, Manalapan, Monmouth County, New Jersey, and had over 150 registered participants.

AAEE Member Michael Johnson, P.E., of Buck, Seifert & Jost, Inc., organized "Run for Water" and already has plans underway for 2010. Registration and event details will be posted on AWWA-NJ's website as information become available at http://www.NJAWWA.org.

AAEE was proud to participate as a sponsor and would like to thank Mr. Johnson for supplying the pictures and information on this event.

Water For People's vision is a world where all people have access to safe drinking water and sanitation; a world where no one suffers or dies from a water- or sanitation-related disease. For more information, visit their website at http://www.WaterForPeople.org.

Michael Johnson, P.E., making announcement prior to the start of the 5K run.

AEESP and AAEE Present the 2009 Frederick George Pohland Medal

The Frederick George Pohland Medal for 2009 has been awarded to Louis J. Thibodeaux, Ph.D., P.E., BCEE. This award was presented on July 28 in conjunction with the AEESP 2009 Conference Banquet in Iowa City, Iowa. Dr. Thibodeaux, Jesse Coates Professor of Engineering of Louisiana State University, has been AAEE board certified in General Environmental Engineering since 2000.

The Frederick George Pohland Medal honors an individual who has made sustained and outstanding efforts to bridge environmental engineering research, education, and practice. Only members of the Association of Environmental Engineering & Science Professors and/or the American Academy of Environmental Engineers are eligible to receive this award.

AAEE and AEESP would like to thank the Pohland family, the Environmental Engineering Foundation (chaired by Charles A. Willis, P.E., BCEE), and other donors to the Frederick Pohland Memorial Fund.

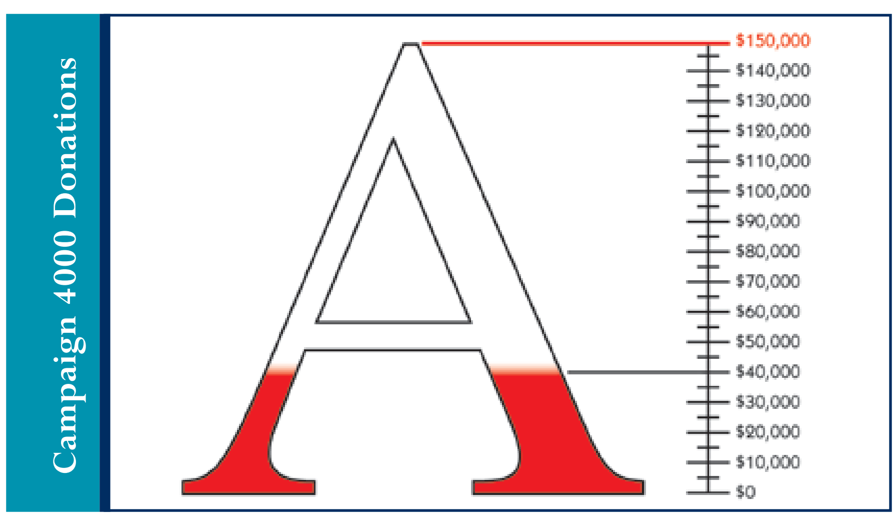
Previous distinguished recipients include: R. Rhodes Trussell, Ph.D., P.E., BCEE (2005); Raymond C. Loehr, Ph.D., P.E., BCEE (2005); C. Herb Ward, Ph.D., P.E., BCEE (2006); George Tchobanoglous, Ph.D., P.E., BCEE (2007); and Makram Suidan, Ph.D., P.E., BCEE (2008). EE

(left to right) AEESP President, Dr. Amy E. Childress; 2009 Frederick George Pohland Medal recipient, Dr. Louis J. Thibodeaux; AAEE President, Dr. Debra Reinhart; and AEESP President-Elect, Dr. Peter Adriaens.

Dr. Louis J. Thibodeaux addresses those in attendance at the 2009 AEESP Conference Banquet.

I was really impressed with the latest *Environmental Engineer.* It is great to see the good things that are being accomplished with the financial base that was built over the last few years.

Timothy G. Shea, Ph.D, PE, BCEE
CH2M Hill
Chantilly, Virginia



CAMPAIGN 4000

Donation/Pledge Form

Yes! I would like to contribute to Campaign 4000 to fund the AAEE 5-Year Strategic Plan to foster the sustained growth and progress of the Academy.

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Please make your check out to AAEE Campaign 4000 and mail to:
American Academy of Environmental Engineers
130 Holiday Court, Suite 100
Annapolis, MD 21401

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Card Number ____________________ Expiration Date ____________

Cardholder Signature ____________________ *Mail charge information to AAEE or fax to 410.266.7653*

Thank you for your financial support in helping the AAEE sustain its continuing growth.

Debra Reinhart, Ph.D., P.E., BCEE

From an early age, Debbie Reinhart had a passion for math. However, as a female growing up in the 60s and 70s, no one suggested she consider engineering as a career option. Those were different times for women in the sciences and engineering, when elementary and secondary school teachers and counselors did not view little girls as future scientists or engineers.

Indeed, Debbie's high school guidance counselor recommended that she attend a certain college because she said she could picture Debbie walking down the scenic brick paths adjoining famous lawns. The academic quality of the sciences or mathematics departments held very little interest for that counselor, despite the fact that she was advising the salutatorian of Seminole High School.

To her counselor's dismay, Debbie did not matriculate at the suggested school. Instead, she enrolled at another small liberal arts school, Rollins College in Winter Park, Florida, where she began her college studies as a math major. Once she took her first college physics

Debbie at Florida Technological University working in Dr. Marty Wanielista's (BCEE) lab

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The Landfill Lady

class, however, Debbie knew she wanted a career that allowed her to apply her math skills rather than delving into only theoretical mathematics.

In her sophomore year at Rollins College, she started investigating the engineering field and found Florida Technological University (now known as the University of Central Florida) a few miles away from Rollins in the metro Orlando area. Immediately, she felt comfortable with FTU's Environmental Engineering program, which held the serendipitous claim to being the oldest accredited Environmental program in the U.S [at the baccalaureate level]. Transferring from Rollins with her math training in hand, she started and completed the remaining requirements for a B.S.E.E. within two busy years. Following graduation from FTU, Debbie moved to Atlanta, GA, eventually earning two degrees from Georgia Institute of Technology in Environmental Engineering.

Bioreactor landfill expert

Debbie's Ph.D. advisor at Georgia Tech was Dr. Fred Pohland, who is widely recognized as the father of the modern municipal solid waste bioreactor landfill practice. As befits a graduate student mentored by Dr. Pohland, Debbie's most notable contributions may be found in the field of solid waste management, specifically her internationally recognized efforts as a leading expert in bioreactor landfills.

A properly designed and operated bioreactor landfill results in accelerated stabilization of the waste. This goal is accomplished primarily by the addition of moisture to the solid waste to create an environment favorable for the microorganisms responsible for waste decomposition. This approach differs greatly from the traditional approach of managing solid waste landfills in a fashion that discourages waste decomposition by minimizing moisture entrance into the landfill. The newer technology offers many advantages, including the rapid stabilization of waste resulting in the potential for recovery of airspace, in situ treatment and storage of leachate, potential reductions in long-term and post-closure care costs and liability, and more reliable production of landfill gas for energy recovery (in the case of anaerobic landfills).

Debbie's work with bioreactor landfills has produced operational, monitoring, and design information that optimizes the landfill process, reducing the impact of landfilled waste on the environment. Most of her work takes place in the field at full-scale operating landfills; however, her research also relies on computer modeling and laboratory research. Significant funding sources include the US Environmental Protection Agency, EPA Region IV; the Gulf Coast Hazardous Research Center; the National Science Foundation; and the Florida Center for Solid and Hazardous Waste Management.

In 1996, she traveled to New Zealand to receive an international award from the International Solid Waste Association recognizing the importance of her bioreactor landfill publications. Debbie received a Women's International Science Collaboration Program Award from the American Association for the Advancement of Science to travel to Moscow in June 2003, where she worked with Russian scientists on bioreactor landfill modeling. She received National

"I have tremendous respect and admiration for Debbie. It is thus, with great pleasure, that I share with you some of my thoughts and comments.

I was one of Debbie's Ph.D. students (attended UCF from 2001 to 2006). She was an excellent advisor. Being a former student of hers, I can tell you that Debbie is a wonderful teacher that is able to effectively describe and explain theories and concepts in ways all students can understand and relate. She is undeniably invested in ensuring all students receive the highest possible standard of education. She inspires her students to persevere when faced with unforeseen, and often at first glance, seemingly impossible to overcome obstacles, to explore new and innovative technologies being practiced in the engineering community, and to challenge themselves to work to their utmost potential.

Debbie is also an incredible mentor, particularly to young women interested in engineering. As a young woman myself, I often turned, and continue to turn, to Debbie for advice and support. Debbie has had an extraordinary impact on me, both professionally and personally. As a student, Debbie was constantly available to discuss not only academic or research issues, but also my future aspirations. She helped craft a plan to put me on track to achieving all of my professional goals. Following my graduation from UCF, Debbie has continued to serve as my mentor and friend. As a young Assistant Professor, it is comforting to know that I can always count on her to provide encouraging words and/or good advice as needed. She, no matter how busy, is always just a phone call (or email) away. I gained a tremendous amount of knowledge from Debbie that I am certain has made me a better Professor.

It goes without saying that Debbie's research record is impeccable. Debbie has made a significant impact in the solid waste field, particularly for being one of the leading researchers in the bioreactor landfill area. Her research has greatly influenced the way landfills are viewed and operated. She is well respected by all in the field, both nationally and internationally, and is often asked to serve on various boards/committees in which her expertise is desired. There is not a solid waste conference that one can attend in which Debbie is not known. I have always been in awe of her significant research contributions."

– **Nicole D. Berge, Ph.D.**
Assistant Professor, Department of Civil and Environmental Engineering
University of South Carolina

Science Foundation funding to conduct collaborative solid waste management research in Jordan in 2000 and 2003.

Debbie wrote the *Design and Operation of the Bioreactor Landfill* (published in 1998) with Tim Townsend of the University of Florida, the only available text on the bioreactor landfill. As a consequence of her many publications, she receives requests for information on bioreactor landfills from researchers around the world. She frequently makes presentations at international conferences, seminars, governmental agencies, and universities. She has spoken at many national conferences, including the Geotechnical Research Institute Symposium and the US Composting Council's annual meeting. She played a leading role in briefings for the US EPA on Bioreactor Landfills in 2000 and 2003.

She has also been asked to present on this topic throughout the United States and in Australia, France, Wales, Finland, Sweden, New Zealand, China, Bahrain, Singapore, Japan, and many other places. Journalists from the *Wall Street Journal* and other publications have interviewed her on bioreactor landfill issues. A reviewer of a funded National Science Foundation proposal recently noted, "One of the investigators, Debra Reinhart, is a reputable engineer and one of the leaders in solid waste treatment and management in Florida and the nation."

The road back to UCF

After graduating from FTU, Debbie began her environmental engineering career at Keck and Wood, a small consulting firm in Atlanta, Georgia. During her early years of practice, she focused on wastewater treatment. At Keck and Wood, several of her more interesting projects involved operating a mobile wastewater treatment pilot plant built wholly inside of a horse trailer by one of the firm's principals. The pilot plant was designed to simulate an activated sludge process and was used at municipal wastewater plants in Carrollton and Albany, Georgia, to assist in diagnosing operational problems. Debbie got her first taste of engineering research while operating this pilot plant.

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Three years later, Debbie joined the City of Atlanta's Research and Development Division of the Bureau of Pollution Control, run by Dr. Phil Karr. For the next five years, Debbie worked at some of the largest wastewater treatment facilities in the US, assisting in improving operations. The Division investigated large-scale breakouts of Nocardia, partial nitrification that increased chlorine demand, grit removal processes, novel biological treatment processes, and other challenging problems. The Division was a unique organization modeled after similar groups in Chicago and Los Angeles, and essentially was a small specialized engineering research program staffed by civil employees. Before she left, Debbie had been promoted to Chief of the Division.

After a brief stint at CH2M Hill in Atlanta, Debbie returned to Georgia Tech full-time to luxuriate in working on her Ph.D. without the distraction of simultaneously earning a living, having earlier completed an MS degree there while working full-time as a consultant. It was at this point that Debbie moved from wastewater treatment and began her solid waste management research career. Her Ph.D. dissertation explored the fate of hazardous pollutants co-disposed with municipal refuse. She documented the ability of landfills to assimilate a variety of organic trace pollutants, and her publications in this area continue to be cited 20 years later.

Debbie returned to Florida and her UCF Alma Mater in 1989 as an assistant professor in the Civil and Environmental Engineering Department. Since then, she has maintained an active research and teaching program, advising 11 doctoral students (eight have graduated to date) and 45 master students (all have graduated), written over 200 publications and presentations, received five patent awards, and published four books. Most recently, the University recognized her by naming Debbie a Pegasus Professor, the highest faculty honor awarded at UCF.

In addition to traditional teaching and research faculty duties, Debbie served as Associate Dean for the College

Top: Debbie and colleagues, Dr. Chris Clausen and student Aamod Sonawane, investigating a zero-valent iron permeable wall in Denver, CO.
Bottom: Debbie with student, Sandeep Saraf, conducting field work at a landfill.

Left: Debbie and Richard with daughter Richelle and son Geoffrey. Right: Debbie and Richard

"Dr. Debbie Reinhart is the consumate professional, and is both a pleasure and a challenge to work with - a pleasure, because her technical expertise and interpersonal skills make it possible for her to dispose of difficult issues with the utmost ease, and a challenge because her next difficult assignment to you is usually just seconds away."

– Cecil Lue-Hing, D.Sc., P.E., DEE, NAE
President, Cecil Lue-Hing & Associates, Inc.

"Debra Reinhart and I have been co-chairs of the ASCE Solid Waste Engineering (SWE) Committee for a number of years. She is an active participant at monthly SWE conference calls, has coordinated a webinar session for each webinar series offered by the SWE Committee for the past four years, is a loyal supporter of our efforts and a pleasure to work with."

– Carol Diggelman, Ph.D., Professor
Architectural Engineering & Building Construction Department
Milwaukee School of Engineering

of Engineering for 13 years, as an Interim Chair of her Department, as Interim Director of the NanoScience Technology Center, and is currently an Assistant Vice President for Research and Commercialization for the University.

In addition to her work in bioreactor landfills, Debbie has also made important contributions in the field of environmental remediation. She was part of a team comprised of chemistry and engineering faculty from UCF and NASA that developed a process using zero-valent iron to treat chlorinated non-aqueous phase liquids and groundwater contaminants. In recognition of the importance of this work the team members were honored as Tech Museum Laureates in 2007 (The Tech Museum of Innovation); inducted into the 2007 Space Technology Hall of Fame; granted the 2006 NASA Invention of the Year, and the 2006 Commercialization of the Year awards; received the 2006 Award for Excellence in Technology Transfer presented annually by the Federal Laboratory Consortium for Technology Transfer (FLC); and received the 2002 Grand Prize for University Research from the American Academy of Environmental Engineers. The team's discoveries generated four patents, which joined a patent Debbie had earlier received for her work with landfill gas emissions when she patented a device to measure emissions from the landfill surface.

Serving the Engineering Profession

Debbie also provides significant professional service to the engineering profession. She is a Fellow of the American Society of Civil Engineers. She has served on the boards of two national organizations, the American Academy of Environmental Engineers and the Association of Environmental Engineering and Science Professors; a national research foundation, the Environmental Research and Education Foundation; and one state organization (the Florida section of the Air and Waste Management Association). She currently holds the post of President of the American Academy of Environmental Engineers.

Debbie recently co-chaired a task force with Robert Baillod that created the Environmental Engineering Body

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Debbie and Richard at a tandem rally in Door County, WI.

of Knowledge, which defines the knowledge, skills and abilities needed to practice environmental engineering at the professional level. She has also chaired two national American Society of Civil Engineer committees, served on ten national committees, and organized numerous symposia, sessions, and conferences. Debbie reviews or has reviewed for more than 25 journals and organizations.

She is a registered professional environmental engineer, and the American Academy of Environmental Engineers board certified her in solid waste management in 1994. She has been on the editorial board for three archival journals. She has received editorial awards from the American Society of Civil Engineers *Journal of Environmental Engineering* and the *Waste Management Journal*. She is also an environmental engineering program evaluator for ABET Inc., the engineering program accreditation organization for colleges and universities.

The Mentor

Debbie has a special interest in promoting underrepresented groups in science and engineering. She regularly mentors young women in engineering. She was the founding president of the FTU student chapter of the Society of Women Engineers

"Her work on organizing and finishing the Body of Knowledge for Environmental Engineering was a masterful job of project management."

– Brian P. Flynn, P.E., BCEE
Principal, MRE, Inc.

"I am constantly amazed by the breadth of activities in which Debbie has excelled and assumed a leadership role. She has established herself as a leading expert on landfill research while also finding time to author textbooks and assume a leadership role in university administration and profession organizations (ASCE and AAEE)."

– Morton Barlaz, Ph.D., P.E., BCEE
Professor and Associate Head, North Carolina State University

"Dr. Debra Reinhart has been here at UCF for 20 years, and I have always enjoyed working with her and conversing with her. She has been a very successful researcher and has served as interim department chair and as an associate dean of the college of engineering. Throughout all that administrative time, she continued to conduct research and mentor PhD students. Debbie has a great personality and a sterling character. She is reliable and hard working, and she really cares about her students. She is especially outstanding as a role model for young women who pursue advanced degrees in engineering, and has always been a strong advocate in our college for female students, faculty, and staff. I am very pleased to be able to call her both a friend and colleague."

– C. David Cooper, Ph.D., PE, QEP
Professor of Engineering and Graduate Coordinator
Civil, Environmental and Construction Engineering Department
University of Central Florida

"I have worked with Debbie for a number of years on Academy leadership initiatives and other programs affecting the engineering profession. Not only is she an extremely intelligent and articulate spokesperson for the Academy but I find her to be a down to earth thinker with a practical side that helps sort out very complex issues. This is a rare combination of attributes that make her a very special engineer and person".

– William P. Dee, P.E., BCEE
President & CEO, Malcolm Pirnie, Inc.

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while a student, and currently serves as faculty advisor of the same UCF chapter. She regularly participates in the UCF Expanding Your Horizons conference for middle school girls, frequently as the coordinator, in an effort to show young women the opportunities available to them in the sciences and engineering. She also judges high school science fairs and often speaks at high schools and other universities.

As chair of the UCF Commission on the Status of Women, she coordinated data collection and report preparation regarding female UCF students, faculty, and staff. She received a National Science Foundation grant that allowed UCF to enable children living in a predominately African American Orlando community to become more aware of engineering careers. In recognition of her efforts in this area, she received the 2005 Legends and Legacies Leadership Award at the National Conference on

"I met Debbie as a student at Georgia Tech. I had just arrived from Puerto Rico in September 1979 to start my graduate studies in Sanitary (Environmental) Engineering, with a focus on wastewater treatment processes. Debbie was a part-time student there as well, working full-time during the day at the City of Atlanta Bureau of Pollution Control, while going to school at night. Every semester, at least one course was offered at night for students such as Debbie, and in that first semester night course, we met. She started a conversation to introduce herself, asked about my heritage, and soon the conversation went beyond school topics and into our lives. I didn't have many friends as I had just arrived to the country and English was my second language, but we struck a friendship right away thanks to her welcoming and easy-going demeanor, her balanced approach to work and life, and her inquisitive mind. I feel so thankful to have met her! I didn't know it then, but Debbie has turned out to be a very important person in my life, both professionally and personally. Besides the common interests that we shared in our professional lives, we shared in the challenge of also being working wives and mothers, and trail-blazers for women in our industry. We've maintained our friendship and professional relationship for almost 30 years!

I worked for and with Debbie [at the Technical Services Branch of the City of Atlanta Bureau of Pollution Control] for nearly three years. What I loved most about working for her was how generous she was with her intellect, her time, and her teaching and mentoring skills. The way she challenged our thinking, offered perspectives without providing hard direction or answers to the questions we were charged with answering ourselves, and created a team in the Bureau's Technical Services Branch that charted new paths in wastewater research & development and plant operations, was truly excepttional.

Perhaps 12 or 15 years ago, Debbie was successful in securing a grant for her school to bring guest speakers to address the young women aspiring to careers in science and engineering. This included both enrolled college students and some high school candidates. Debbie asked if I'd be willing to participate and speak to her students about my experiences in the environmental engineering field, as a consulting engineer and as a woman and Hispanic in a traditionally male-dominated field of practice. I will never forget how many of them reached out, the questions they asked, and the stories they shared. Even today, Debbie hears from some of her students from that day, who thank her for having given them the opportunity to meet practitioners they could 'relate' to and be inspired and motivated by. This is the kind of professional that Dr. Debra Reinhart is — not just an outstanding technologist and educator, but also someone who truly understands the value of networking and providing a well-rounded perspective on any issue, the need for role models and mentors for our young students and professionals, the power of working together to challenge each other and create new synergies and opportunities, and the full spectrum of what is possible if we only dare to imagine and dare to dream."

– ***Liliana Maldonado, P.E., BCEE,***
Senior Vice President and Northeast Regional Manager, CH2M Hill

Leadership Diversity, and the 2005 Woman of Distinction Technology Award from the Citrus Council Girl Scouts.

The Garbage Queen

Debbie grew up in Seminole, Florida, which is located on the west coast of Florida near Tampa Bay. Her father was a psychologist, her mother a secretary. Her older sister, Jill Spence received a degree in Engineering Technology from FTU and is a computer analyst for UNUM, an insurance company. Their father often jokingly expressed concern about how he managed to raise two female engineers!

Debbie met her husband of 33 years at Rollins College, and they were married a few days following Debbie's graduation. Richard fondly calls Debbie "the Garbage Queen," and to his knowledge no one else has laid claim to that honorific title. He practices law in Orlando.

Despite planning for a wedding scheduled a week after final exams ended, Debbie graduated from FTU summa cum laude with a 4.0/4.0 GPA, the first graduate to do so in the FTU College of Engineering. She and Richard have two children; Geoffrey is a Florida State University graduate and an accountant with an Orlando law firm. Richelle is a sophomore at Georgia Tech majoring in Biomedical Engineering; she wants to be a medical doctor.

When she is not actively pursuing academic and professional activities, Debbie joins Richard on their sailboat which is kept near Cape Canaveral, or is the powerful "stoker" on the back of one of their two tandem bicycles. They have traveled with their tandem bicycle for trips to the San Juan Islands; Colorado Springs, CO; Monterey, CA; the Natchez Trace, MS, and most recently, Door County, WI. Most every Saturday morning when Debbie is in town you can find them on the road doing a quick 18-25 mile jaunt on the roads or bike paths in Central Florida. EE

"Debra Reinhart and I have been co-chairs of the ASCE Solid Waste Engineering (SWE) Committee for a number of years. She is an active participant at monthly SWE conference calls, has coordinated a webinar session for each webinar series offered by the SWE Committee for the past four years, is a loyal supporter of our efforts and a pleasure to work with."

– Carol Diggelman, Ph.D., Professor
Architectural Engineering & Building Construction Department,
Milwaukee School of Engineering

TEXAS A&M UNIVER

Congratulates

Our National Science Foundation CAREER Award Winners in the Frank H. Dotterweich College of Engineering

Jianhong-Jennifer Ren, Ph.D.

Associate Professor, Environmental Engineering

Project: Effects of Particle Aggregation/Disaggregation and Precipitation on Sediment and Contaminant Transport

Yifang Zhu, Ph.D.

Associate Professor, Environmental Engineering

Project: Effects of Volatility and Morphology on Vehicular Emitted Ultrafine Particle Dynamics

David Ramirez, Ph.D.

Associate Professor, Environmental Engineering

Project: Research and Education of Adsorption and Desorption of Air Pollutants on Engineered Nanomaterials

TEXAS A&M UNIVERSITY KINGSVILLE

Third A&M-Kingsville Environmental Engineering Faculty Member Wins National Science Foundation CAREER Award

Department making name for itself nationally with its researcher-educators


Dr. David Ramirez

For the third time, a faculty member from Texas A&M University-Kingsville's environmental engineering department has been awarded more than $400,000 from the National Science Foundation (NSF) through their respected Faculty Early Career Development (CAREER) Program.

The CAREER Program offers the NSF's most prestigious awards in support of the early career-development activities of those teacher-scholars who are most likely to become the academic leaders of the 21st century. The program named Dr. David Ramirez, assistant professor of environmental engineering, one of those likely academic leaders.


Dr. Yifang Zhu

Ramirez joins assistant professor Dr. Yifang Zhu and associate professor Dr. Jennifer Ren as the third faculty member from the A&M-Kingsville environmental engineering department to receive a CAREER award in the last four years. The three awards, combined, total more than $1.2 million.

"The standard of excellence being set by Dr. David Ramirez and our faculty in environmental engineering is truly inspiring," said Dr. Steven H. Tallant, president of Texas A&M-Kingsville.

"The fact that the National Science Foundation has invested more than one million dollars in three of the department's researcher-educators speaks highly of the abilities of Drs. Ramirez, Zhu and Ren. The awards also say that Texas A&M-Kingsville's department of environmental engineering offers a wealth of knowledge to its students, and the opportunity to be a part of important, relevant research in a burgeoning field.

"It is a department that is quickly becoming recognized as one of the leading environmental engineering departments in the country," said Tallant.


Dr. Jennifer Ren

Ramirez is studying what happens when nanomaterials come in contact with air pollutants—do they change form and have negative impacts on human health, safety and the environment?

The specific title of Ramirez's project is "Research and Education of Adsorption and Desorption of Air Pollutants on Engineered Nanomaterials."

Ren received a CAREER award in 2005 for her work in examining the grouping and travel of contaminants in rivers and streams. Zhu received a CAREER award in 2009 for her work in understanding ultrafine particles in vehicular emissions.

"Having three NSF CAREER Award winners in one engineering department at the same time is testimony to the quality of the programs and the faculty, staff and students here at Texas A&M University-Kingsville," said Dr. Kim D. Jones, associate professor and chair of the environmental engineering department. "For the small size of the environmental engineering department with only eight total faculty, I think it is quite a research achievement along with the $2.8 million in research expenditures for the department in 2007."

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Volume 9, Fall 2009

Environmental Engineer: Applied Research and Practice

Instructions to Contributors

PURPOSE AND SCOPE

Environmental Engineer: Applied Research and Practice, is a peer-reviewed journal focused on practical research and useful case studies related to the multi-disciplinary field of environmental engineering. The journal strives to publish useful papers emphasizing technical, real-world detail. Practical reports, interesting designs and evaluations of engineering processes and systems are examples of appropriate topics. Papers relating to all environmental engineering specialties will be considered.

MANUSCRIPT REQUIREMENTS:

Manuscripts should follow the general requirements of the ASCE authors' guide (http://www.pubs.asce.org/authors/index.html#1) and should be submitted electronically in WORD format to the Editor and Assistant Editor.

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All papers submitted to the journal are subject to critical peer review by three referees, who have special expertise in a particular subject. The Editor will have final authority over a paper's suitability for publication.

CATEGORIES

Papers may be submitted in the following areas:

Applied Research

Original work presented with careful attention to objectives, experimental design, objective data analysis, and reference to the literature. Practical implications should be discussed.

Review

Broad coverage of an environmental engineering application or a related practice with critical summary of other investigators' or practitioners' work.

Practical Notes

Novel methods that the author(s) have found to be sufficiently successful and worth recommending.

Case Studies

Recently completed projects or studies in progress that emphasize novel approaches or significant results.

Design/Operation

Conceptual or physical design or operation of engineering systems based on new models or techniques.

Management

Papers describing novel approaches to problems in environmental management, or to the global, sustainability or business asects of environmental engineering.

ABSTRACT

An abstract of up to 200 words should be provided, including a statement of the problem, method of study, results, and conclusions. References, tables, and figures should not be cited in the abstract. Up to six key words or terms should be included for use by referencing sources.

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INTEGRATING THE NATURAL STEP ELEMENTS INTO ENVIRONMENTAL MANAGEMENT SYSTEMS

James J. Newton, P.E., BCEE[1]

ABSTRACT

This paper introduces concepts of sustainability with emphasis on the Natural Step principles. It describes the elements of an Environmental Management System (EMS) and discusses how an EMS can ensure sustainability by using portions of the Kent County (Delaware) Regional Wastewater Treatment Facility's (KCRWTF) Environmental Health and Safety Management Plan as an example. The KCRWTF is the first wastewater facility in the United States to be certified to the ISO 14001, OHSAS 18001, and the National Biosolids Partnership's EMS standards.

WHAT IS SUSTAINABILITY

An Internet search for the definition of sustainability will provide a wide variety of links. There are over thirty definitions for the word as it is currently used. One of the most common (World Commission on Environment and Development, 1987) defined sustainability as "meeting the needs of the present generation without compromising the ability of future generations to meet their needs". Mihelcic et al (2003) elaborated on this definition by defining sustainability as "a condition in which the use of natural resources and cycles in human and industrial systems does not lead to diminished quality of life due either to losses in future economic opportunities or to adverse impacts on social conditions, human health and the environment." This definition was recently adopted in the Environmental Engineering Body of Knowledge (AAEE, 2009).

Many organizations look upon sustainability as a union of three distinct areas: environmental sustainability, economic sustainability, and social or ethical sustainability. This concept has often been referred to as "the triple bottom line" which was first defined by John Elkington (1994) and also referred to as "the three e's: environment, economics and ethics" or the "three p's: people, planet and profit". In the past, many organizations have used the word "or" as in environmental sustainability or economic viability, environmental sustainability or social (ethical) progress, social progress or economic viability. Current sustainability concepts typically replace the "or" with "and".

Being Sustainable

There are many benefits associated with operating a sustainable organization. Some of these include:

- Reduced energy, wastes, and costs
- Differentiating sustainable organizations from others
- Sidestepping future regulations
- Creating innovative processes and products
- Opening new markets
- Attracting/retaining the best employees
- Reduced improper labeling of products
- Reduced legal risks and insurance costs
- Providing a higher quality of life
- Reduced liability from pollutants
- Being closed out of certain markets
- Reduced attacks on an organization's image
- Improving the organization's public and shareholder image
- Reducing supply problems due to raw materials and energy

There are a number of reasons why sustainability is becoming a strategic issue for many organizations. Some of the major reasons include:

- It's a natural extension of other organizational changes
- Natural resources are becoming a limiting factor
- Environmental issues now involve global consequences
- Health concerns are gaining importance
- Being sustainable produces many unintended benefits
- Energy supplies pose a significant threat
- Associated with these problems are new opportunities

A truly sustainable organization can be compared to a wheel. The spokes of the wheel represent various parts of the organization including its employees, the products it promotes, the revenue it generates, the raw materials it uses, the natural resources it uses and the byproducts it generates. The rim of the wheel represents the various constituencies it affects. These might include: the environment, its customers, suppliers, stockholders, the community

[1] Kent County Department of Public Works

in which it operates, and the various competitors and other industries it interacts with. In a sustainable world, all of this is in balance and the wheel rotates properly. If any one of the spokes or rim constituencies is out of balance, the wheel might wobble or collapse.

Sustainability Principle Models

There are a number of sets of principles that describe the attributes of a truly sustainable organization. The Permaculture Principles developed by Mollison and Holgrem (1978) represent one of the early developments. Several other sets of principles have been developed since 1995. A very recent set of principles is the International Organization for Standardization's (ISO) proposed Guidance on Social Responsibility (ISO 26000) that is due to be published in draft form in October 2009. Edwards (2005) summarizes the various sets of sustainability principles. Typically, these sets differ in their scope (local, regional, national, international) and/or by sector (government, business, industry, or society) to which they apply.

The Natural Step

In 1988, Dr. Karl-Henrik Robert (a practicing clinician and cancer researcher) began the process of developing the principles and objectives that have become known as The Natural Step.

Robert convened a group of over 100 Swedish scientists and asked them to develop a vision for a sustainable society based on the scientific principles. The Natural Step framework (Robert, 1991) was the result of this effort and is becoming widely recognized.

In this framework, there are four underlying principles or conditions and four guiding objectives.

These system conditions are:

- Nature should not be subject to systematically increasing concentrations of substances extracted from the Earth's crust;
- Nature should not be subject to increasing concentrations of substances produced by society;
- Nature should not be subject to systematically increasing degradation by physical means; and
- People should not be subject to conditions that systematically undermine their capacity to meet their needs.

These conditions can be converted to four objectives that are more easily understood:

- Eliminate our community's contribution to fossil fuel dependency and to the wasteful use of scarce metals and minerals;
- Eliminate our community's contribution to dependency upon persistent chemicals and the wasteful use of synthetic substances;
- Eliminate our community's contribution to encroachment upon nature; and
- Meet human needs fairly and efficiently.

To apply The Natural Step, Boisvert et al. (1999) recommend an A-B-C-D approach: Awareness, Baseline Analysis, Compelling Vision, and Down to Action. Kent County chose to align its program with The Natural Step because of its simplicity and scientific basis.

ENVIRONMENTAL MANAGEMENT SYSTEMS

An environmental management system (EMS) is a set of processes and practices that enable an organization to reduce the environmental impacts from its operations and increase efficiency. It helps the organization to systematically manage its environmental "footprint." Alternatively, according to the ISO definition (ISO, 2004) an EMS is "a part of an organization's management system used to develop and implement its environmental policy and manage its environmental aspects." It is built upon the concept of continuous improvement and follows a four element Plan-Do-Check-Act cycle. The EMS is an evolving process and is consistently modified to accommodate new information, changing circumstances and changes in organization priorities.

The critical components of each of the four elements are:

- Planning, includes identifying environmental aspects and establishing goals [Plan];
- Implementing, includes training and operational controls [Do];
- Checking, includes monitoring and corrective action [Check]; and
- Reviewing, includes progress reviews and acting to make needed changes to the EMS [Act].

There are a variety of reasons that an organization may develop and implement an EMS. The reasons are many and varied and often depend upon the type of organization. A business with international offices has different reasons than a public agency to develop and implement an EMS. Table 1 provides a list of the most common of these reasons.

Some disadvantages to developing and implementing an EMS relate to the costs associated with development of the program and include:

- An investment of internal resources, including staff/employee time;
- Costs for training of personnel;
- Costs associated with hiring consulting assistance, if needed; and
- Costs for technical resources to analyze environmental impacts and improvement options, if needed.

Critical factors that assure the success of any management system include:

- Commitment from senior management;
- Designated staff including a Core team to act as a cheerleader and a representative trained in the program;
- Involvement of all employees in the covered fenceline;
- Dedicated resources;
- A link to the overall strategic planning of the organization;
- Sufficient time to develop and implement the program;
- Proper follow through on the checking and acting components; and
- A willingness to make the cultural shift required for the program to succeed.

The ISO 14001 guidance lists 17 elements, shown in Table 2, as the foundation of an EMS.

Several documents and publications

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cover the various elements of an EMS in detail. One of these is the US EPA publication "Achieving Environmental Excellence: An Environmental Management Systems (EMS) Handbook for Wastewater Utilities," (US EPA, 2004).

INCORPORATING SUSTAINABILITY INTO THE KENT COUNTY FACILITY

The Kent County Regional Wastewater Treatment Facility (KCRWTF) is used as an example to illustrate how sustainability concepts can be incorporated into the EMS at a wastewater facility. The KCRWTF is a 16 million gallon per day (MGD) biological nitrogen removal (BNR) wastewater treatment plant located in Kent County, DE. The plant treats wastewater from all of Kent County and portions of Sussex and New Castle Counties. Its approximate service population is 130,000. The system serves a mix of residential, commercial and industrial clients, with industrial flow contributing 25% of the total.

TABLE 1
Reasons for Developing and Implementing an EMS

Ensure environmental/regulatory and legal compliance	Required as a part of a compliance settlement
Assist with employee succession and retainage	Improve public image
Save money and other resources	Improve environmental performance
Improve operating efficiency	Obtain a competitive advantage
Provide examples of leadership	Reduce environmental risks
Quality for EPA and other recognition programs	

TABLE 2
Elements of an EMS

Environmental Policy	Identifying Environmental Aspects
Legal and Other Requirements	Objectives and Targets
Environmental Management Program(s)	Structure and Responsibility
Training, Awareness, Competency	Communications
EMS Documentation	Document Control
Operational Control	Emergency Preparedness/Response
Monitoring and Measuring	Nonconformance and Corrective Actions
Records	EMS Auditing
Management Review	

FIGURE 1
Aerial Photo of Kent County Regional Wastewater Treatment Facility

An industrial pretreatment program ensures that local industries (primarily food processors) meet minimum wastewater treatment standards and do not affect the plant. The facility discharges into the Murderkill River, a tributary of Delaware Bay.

The collection system consists of approximately 80 pump stations and over 200 miles of force main and gravity sewers. There are currently five contract users, which include the cities of Dover, Milford, Smyrna, Camden-Wyoming and the Dover Air Force Base. Another city, Harrington, will be added in 2010. All major cities in Kent County will then be on the system.

The KCRWTF provides biological nitrogen removal using the Parkson Biolac® treatment system. The water is first treated by screening and grit removal, and flows into one of two 14 million gallon basins where it is aerated, then sent to four clarifiers and disinfected using chlorine gas and then dechlorinated using sulfur dioxide gas. Biosolids are dewatered on belt filter presses, lime stabilized, and indirectly dried. The resulting biosolids, referred to as Kentorganite, are land applied on local farms as a soil amendment and minor source of nitrogen and phosphorus. Kentorganite is in great demand by local farmers.

Sustainability Policy

One of the first elements that an organization establishes as a part of its EMS is the environmental policy. This element provides the guiding principles for the entire EMS. The policy provides the direction for the organization and the commitment of resources to meet this commitment. This is the element where the sustainability principles discussed earlier are stated for the organization. This is the first step towards ensuring that the organization has made the commitment to sustainability and that the key principles are in place to guide all future actions. The policy provides the compass that guides the EMS on its journey.

The KCRWTF began its EMS path by participating in the US EPA's Third EMS Initiative for Public Agencies (also referred to as MUNI III). It was one

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of nine public agencies to participate in the two-year process overseen by the Global Environment Technology Foundation (GETF). The program used the ISO 14001 standard as the model and allowed each agency to define its fenceline (operations to be covered). The KCRWTF chose to include all plant operations and its collection system. Under the program, a Core Team and an environmental management representative were designated to lead the effort.

The EMS Core Team initially developed an environmental policy that was adopted by the Kent County Commissioners for the facility, and that committed the facility to:

- Compliance with all applicable environmental laws and regulations;
- Meeting the National Biosolids Partnership's (NBP) EMS Code of Good Practice;
- Continuous improvement of its EMS program;
- Communicating its vision and EMS program to all interested parties; and
- Promoting pollution prevention.

In 2005, under the direction of the Kent County Commissioners, the policy was revised to address employee health and safety in order to meet the OHSAS 18001 requirements; and this year, a commitment is being added to sustainability principles. This integrated policy is implemented through the KCRTF Environmental Health and Safety Management Plan (EHS-MP).

Sustainability Aspects, Objectives and Targets

An inventory of the environmental aspects of operations is an important step in the EMS process. In compiling the inventory, the EMS team can use sustainability principles as a means to evaluate their operations and how they impact the environment. By using these principles, the team can focus on more than mere regulatory compliance. These principles help the team to identify all possible impacts.

The sustainability principles can help to establish environmental significance of an operation. The activities that take place within the organization and affect the environment or worker health and safety can be evaluated using sustainability principles. This evaluation indicates which activities or operations have either a positive or negative affect on promoting a sustainable organization. This approach looks upstream at the processes covered and can help the organization assess both local and global impacts on the environment. The alternative that is commonly used is to view only downstream effects and look narrowly at the effects upon the air, land, and water after the process has happened. Consideration of various electrical energy sources is an example of alternatives that could be prompted by looking upstream.

The inventory can be built by evaluating the activities of the organization using the sustainability principles. This might involve evaluating the use of electricity against the first condition of not impacting materials from the earth's crust. Under this scenario, the use of fossil-fueled electric power generation would be a negative aspect. Another objective could involve the use of hazardous chemicals, such as chlorine and sulfur dioxide in a disinfection process, which would be subject to the second condition.

The sustainability criteria can also be applied to rank the operations or activities identified in the inventory according to their significance. The top three to five ranked aspects could then be addressed in the next phase of the EMS.

As a part of the EMS development, the KCRWTF Core Team determined its significant environmental aspects. The three most significant aspects were directly related to The Natural Step's sustainability criteria. They included the use of chlorine gas as a disinfectant and sulfur dioxide gas in the dechlorination process, the use of fuel oil in the biosolids thermal heaters, and the use of fossil-fuel based electricity.

Once the significant aspects have been identified, the organization's EMS must address either how to control them or how to reduce them. Sustainability principles can greatly facilitate the determination and setting of objectives and targets, one of the most important parts of the EMS. In order to be effective, objectives need to be highly specific, measurable, and have a specific target date by which they should be met. They should be in alignment with the environmental policy and vision, and should be established to meet long-term goals, rather than short-term accomplishments. It is important to have a mix of short-term goals and long-term goals with the shorter term goals designed to establish momentum within the program.

A conventional approach to setting management objectives looks at current trends and forecasts future trends to arrive at decisions. This approach takes current trends and projects them into the future.

Under the sustainability principles, a different approach is recommended. This approach is called back-casting and relies on looking at a future where everything is sustainable and then projecting back to the current situation. Back casting was first presented as a part of The Natural Step program. The objectives are then designed to meet the future vision of sustainability.

The Environmental Management Plan

The environmental management plan follows from the established objectives and targets. This plan defines the tasks necessary to meet the objectives within the available resources along with the timetable for task completion. For the KCRWTF, three objectives were developed to address the three most significant aspects identified by the inventory:

- Use of chlorine and sulfur dioxide for disinfection/dechlorination.
- Biosolids drying and management: fuel substitution and kiln combustion
- Use of fossil-fuel based electricity

These objectives were incorporated into their Environmental Management Plan with target dates specified. The KCRWTF Core Team, as a part of its quarterly review, looks over the objectives and targets and determines if sufficient progress has been made

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towards achieving them. Once the objectives have been achieved, new objectives are developed to allow for the continuous improvement of the program to move forward.

Substitution of UV for Chlorine and Sulfur Dioxide

The first significant objective to be addressed by the program was to remove the chlorine and sulfur dioxide gases from the plant because of their potential environmental, health, and safety hazards. The chlorine gas system will be replaced by an UV system by the end of 2009. With the elimination of chlorination, the need for dechlorination using sulfur dioxide gas will also be eliminated. The chlorine gas system has been in use since the plant's startup in 1973 and has been extremely safe and reliable. However, because of chlorine's highly hazardous nature and the remote possibility of it being a target of opportunity, it was felt that elimination of the chemical would serve a number of purposes.

The objective was written to reduce or eliminate the use of chlorine gas by 2012. There were a number of steps that were defined in the EHS Management Plan. The first step was to evaluate the options. A Capstone study was conducted by University of Maryland students as a part of their graduate degree program that showed UV as a viable option. The study was reviewed by the Core Team and accepted, and a design engineering firm was selected. Currently, the design process is being finished. The design process selected the Severn Trent Microdynamics® UV system that uses microwaves to generate the UV radiation.

The facility will be the first in the US and the largest in the world to use the innovative UV system. The Microdynamics® system utilizes UV light bulbs that have no filaments and are guaranteed for three years. Typical UV system providers currently only guarantee their lamps for 1 year. The UV lamps also are at full power within 30 seconds as compared to a typical UV system lamp which reaches full power in 1-5 minutes. This allows the UV system to more easily handle increased flows. The lamps, because they do not have a filament inside them, do not generate clouding of the interior of the lamp tubes and thus prevent the decrease of the lamp's effectiveness. Decreased effectiveness would require subsequent lamp replacement. The lamps also operate at ambient temperature, which does not allow for a solids build up on the outside of the tubes. The UV system is normally designed based upon wastewater transmissivity. The lower the transmissivity, the less effective the lamps are. The KCRWTF had a measured transmissivity of 75%, which was excellent for the use of UV. A typical secondary treatment effluent transmissivity is between 60-80%. The KCRWTF pilot tested a 1 MGD unit and found that it produced the same level of pathogen reduction that the chlorine system was producing.

As a part of the project, the aeration basin discharges will be redesigned to allow for flow equalization thus ensuring a more constant flow through the UV system. The change to the UV system will save approximately $100,000 in chemical costs and remove the plant from the US EPA's Risk Management Program (RMP). It will also eliminate the need for evacuation planning around the site and to have a team trained to respond to chlorine leaks. Although the UV system will use electricity, the electricity will be generated by 300 kW of solar photovoltaic panels during daylight hours. This will reduce purchased electricity costs by approximately $15,000 per year. The expected capital costs for the entire UV/solar project will be about $4,000,000.

Biosolids Drying and Management

A second objective was to improve biosolids management by substituting natural gas for fuel oil in biosolids drying and by use of some dry biosolids as a fuel in cement kilns. Changing the thermal fluid heaters from fuel oil to natural gas was projected to reduce air pollution by 20%. The fuel oil fired thermal fluid heaters were replaced with natural gas fired units in 2008, and a thermal energy recovery system is being designed for installation in 2009. The switch to natural gas has reduced nitrous oxide emissions by 95%.

In addition, the entire biosolids treatment process is being redesigned. An innovative solar dryer that will treat about 20% of the biosolids is proposed for 2010. This system will dry the filter pressed sludge cake to 85% solids using passive solar energy as well as heat recovered from the aeration system blowers. The dried biosolids will then be transported to a nearby cement kiln where the cake will be burned in lieu of coal. The revised biosolids process will reduce natural gas usage by approximately 20% and reduce the need for transport trucks and other equipment for land application of Kentorganite on local farms. In addition, the use of polymers and ferric chloride to increase filter press cake solids will be greatly reduced, and the use of lime as a stabilizing agent will be eliminated. However, there will be a reduction in Kentorganite available for the farmers, which would require them to find a more costly alternative for the nutrients and soil amending properties provided by Kentorganite. The use of anaerobic digestion was evaluated, but because the facility does not currently use anaerobic digestion, it is not as cost effective as the solar dryer.

Solar and Wind Power for Plant Electricity

A third significant objective was to move away from fossil fuel fired sources of electricity. The plant is currently planning to design and install a renewable energy facility at the plant which will combine wind, solar, and biomass generation to provide 100% of the needed electricity at the wastewater plant, which is about 30,000 kWh per day or 1.25 MW. The facility intends to install approximately 300 kW of solar electricity to power the new UV system and other portions of the facility by the end of 2009. The remaining major component of the energy facility will be the wind system, which is currently under study. The facility has 4 years worth of wind data at 100', but has just recently installed a three tiered monitoring system that measures wind at 75', 125' and 185'. Once a year's worth of upper level wind data is obtained, it is hoped that there will be sufficient wind to justify the installation of 3-5 MW of wind turbines at the facility. If it proves achievable, the wind system is expected to be installed by 2012. Heating, ventilation, and cooling of the two office buildings located at the facility represents a major use of electricity. A geothermal system that will provide heating and cooling is currently being designed.

Consistency with Natural Step Conditions

A review of The Natural Step conditions shows that the first objective will address system condition number 2 (in a sustainable society, nature is not subject to systematically increasing concentrations of substances produced by society).

The other two objectives will address system condition number 1(in a sustainable society, nature is not subject to systematically increasing concentrations of substances extracted from the Earth's crust).

Sustainability Training, Awareness and Competency

The training, awareness, and competency program is the element of the EMS where the sustainability principles are communicated to all members of the organization. The KCRWTF holds annual EMS awareness training for all of its employees. In the latest training session, a significant portion of the class was devoted to understanding The Natural Step framework and how the KCRWTF is using it to guide its current programs.

Sustainability Progress Measurement

A common phrase used in business today is "what gets measured gets managed." Progress is measured using the three stated EMS objectives as well as some emerging performance indicators such as product life cycle and carbon footprint. Monitoring of progress occurs during the quarterly Core Team meetings. The EMS representative provides a summary of the progress towards the objectives and goals set forth in the program and the Core Team then uses this information to ensure the programs are progressing as anticipated or if not, what changes need to be made to ensure the programs meet the objectives and targets established by the EMS. In addition, the KCRWTF prepares several annual reports to the US EPA and the public about its EMS activities including its progress towards sustainability.

The KCRWTF was the first publicly owned treatment works to be admitted into the US EPA's National Performance Track program. The Performance Track program required an annual report on progress that includes measureable data on progress toward objectives as well as a description of the carbon footprint of the facility. Although the US EPA no longer supports the Performance Track program, the Kent County treatment facility will continue to measure progress toward the goals.

SUMMARY AND CONCLUSIONS

1) This paper describes how the Kent County Regional Wastewater Treatment Facility is using the sustainability principles of The Natural Step in conjunction with the ISO 14001 concepts to incorporate sustainability into an environmental management system.
2) Three sustainability objectives incorporated into the environmental management system at the Kent County Facility serve as examples of how sustainability can be implemented at a wastewater treatment utility. These objectives involved substitution of UV disinfection for chlorine disinfection, submission of natural gas for fuel oil, and dried biosolids for coal along with development of solar and wind power for plant electrical needs.

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SEQUENTIAL CHLORINATION: A NEW APPROACH FOR DISINFECTION OF RECYCLED WATER

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ABSTRACT

Recycled water must be properly disinfected to protect public health. The most widely practiced recycled water disinfection technology is chloramination. However, chloramines are precursors to the carcinogen N-nitrosodimethylamine (NDMA). To address this concern, engineers at the Sanitation Districts of Los Angeles County (Districts) developed the two-step "sequential chlorination" process. In the first step, free chlorine is added to fully nitrified secondary effluent to inactivate pathogens and to react with NDMA precursors, thus reducing subsequent NDMA formation. Chloramines are then added to media filtered effluent to stop formation of trihalomethanes (THMs) and haloacetic acids and to provide further disinfection.

The sequential chlorination process was extensively tested for disinfection efficacy and disinfection byproduct (DBP) formation in the laboratory, at the pilot scale, and at several water reclamation plants operated by the Districts. Results indicate that the process (1) provides effective disinfection against total coliform bacteria and viruses at chlorine contact times well below those required by California regulations for disinfected tertiary recycled paper; (2) reduces NDMA formation by 50 to 85% in comparison to chloramination; (3) produces effluent consistently meeting the total THM limit for recycled water; (4) generates insignificant amounts of cyanide (a DBP of concern); and (5) causes no aquatic toxicity.

INTRODUCTION

The Sanitation Districts of Los Angeles County (Districts) operate 11 wastewater treatment plants serving over five million residents in the Los Angeles County, California. The 11 plants treat a combined average daily flow of approximately 500 million gallons per day (MGD). Seven of the 11 plants are tertiary water reclamation plants (WRPs) that produce over 150 MGD of recycled water. Typical treatment processes at these tertiary WRPs include primary sedimentation, activated sludge with biological nitrogen removal, media filtration, chlorine disinfection, and dechlorination. Approximately one-third of the recycled water is currently reused for groundwater replenishment, landscape and agricultural irrigation, wildlife habitat maintenance, and industrial process water supply; the remainder is discharged to surface water.

Recycled water must be properly disinfected. The disinfection method must be effective for pathogen inactivation, and should minimize the generation of potentially harmful disinfection byproducts (DBPs). In California, disinfection requirements are specified in California Title 22 water recycling criteria. For groundwater replenishment, the recycled water must meet drinking water standards.

Historically, chlorination is the most widely practiced wastewater disinfection technology. Depending on the ammonia level in the water, chlorine may be present as either free chlorine or chloramines. At the Districts' tertiary WRPs, either free chlorine or chloramines may be used for disinfection because these plants are designed to remove nitrogen. Secondary effluents of these plants are considered fully nitrified and usually contain <1 mg NH_3-N/L. Until recently, chloramination was practiced at these WRPs because chloramines produce lower levels of trihalomethanes (THMs) than free chlorine (Kuo et al., 2003). Low levels of ammonia nitrogen (typically 1.0 to 1.5 mg NH_3-N/L) were added to fully nitrified secondary effluent, followed by chlorine addition (8 to 10 mg Cl_2/L) upstream of the media filters. Additional chlorine could be added downstream

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FIGURE 1
Sequential Chlorination at the Districts' Tertiary Water Reclamation Plants

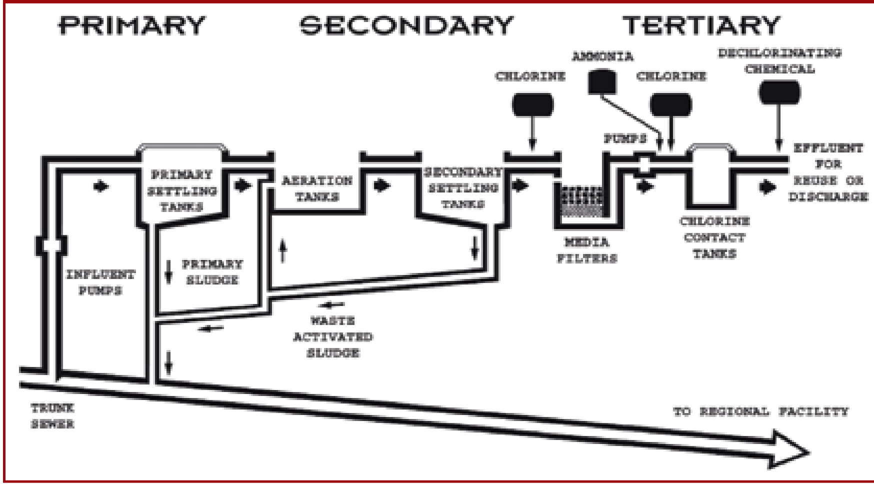

TABLE 1
Sequential Chlorination Research Objectives and Scope

Phase	Objectives	Scope
I	Evaluate DBP formation by sequential chlorination	Laboratory experiments using secondary effluent samples from Long Beach WRP
II	• Verify DBP formation results from laboratory study • Evaluate microbial (coliform and enteric virus) inactivation and aquatic toxicity • Determine operating conditions (i.e., chlorine dose and residual) for full-scale operation	Plant-scale testing at Long Beach WRP, San Jose Creek WRP*, and Whittier Narrows WRP
III	Determine chlorine doses and contact times needed to meet California Title 22 requirements for "disinfected tertiary recycled water" (5-log inactivation of poliovirus or MS2 coliphage and total coliform <2.2/0.1 L)	Laboratory experiments using secondary effluent samples from San Jose Creek WRP* seeded with surrogate viruses (poliovirus and MS2 coliphage)
IV	Verify virus inactivation results from laboratory experiments	Pilot-scale testing using secondary effluent from San Jose Creek West WRP seeded with MS2 coliphage

*San Jose Creek WRP includes two separate treatment systems, San Jose Creek East WRP and San Jose Creek West WRP.

of the filters, if necessary, to maintain sufficient chlorine residual in the chlorine contact tank effluent.

Chloramination has provided effective disinfection. However, researchers recently found that chloramines generate N-nitrosodimethylamine (NDMA), a chemical with high carcinogenic potency (Mitch et al., 2003; Choi and Valentine, 2004; Mitch and Sedlak, 2004; Sedlak et al., 2005). NDMA precursors are chloramines and dimethylamine, a component in the cationic polymer commonly added to the return activated sludge or to the mixed liquor entering the secondary clarifiers to enhance settling and for foam control. In previous work, the Districts attempted to reduce NDMA formation by replacing the cationic polymer with emulsion polymers that do not contain dimethylamine; although this change reduced NDMA formation, the alternative polymers were less effective than the cationic polymer as a settling aid, caused operational issues with the media filters, and were not considered a practical solution for reducing NDMA formation (Huitric et al., 2006). Free chlorine and chloramines may also produce other DBPs such as cyanide (Kavanaugh et al., 2003; Zheng et al., 2004a & 2004b).

Due to these concerns, the Districts decided to replace chloramination with a new disinfection method that would continue to protect public health with its high disinfection efficacy, minimize DBP (specifically THM, NDMA, and cyanide) formation, and have no adverse impact to the environment (i.e., no aquatic toxicity). The new disinfection method should be easily and cost-effectively implemented by using existing infrastructure and practice. To meet these objectives, the Districts' staff conceived the idea of "sequential chlorination" in which chlorine is applied in two steps, as shown in Figure 1.

In the first step of sequential chlorination, free chlorine is added to fully nitrified secondary effluent. Free chlorine rapidly inactivates bacteria and viruses because it is a strong oxidant (Tchobanoglous et al., 2003). It also reacts with NDMA precursors to make them less available for subsequent NDMA formation (Schreiber and Mitch, 2005). Furthermore, free chlorine residual helps to control biofouling on the filter media. In the second step of the process, ammonia and additional chlorine are added to filtered effluent to form chloramines. Chloramines minimize THM formation and provide additional bacterial and viral disinfection. The only change in system configuration from chloramination to sequential chlorination was to relocate the ammonia addition line from upstream to downstream of the media filters.

OBJECTIVES AND SCOPE

The main objective of the study was to evaluate the disinfection performance and DBP formation of the sequential chlorination process. The evaluation was conducted in four phases (Huitric et al., 2007, Huitric et al., 2008). Because DBP formation prompted this investigation, the first two phases focused on DBP formation, first at the laboratory scale (Phase I), then at the plant scale (Phase II). Phase II also examined regulatory compliance with respect to microbial inactivation and aquatic toxicity. The last two phases continued to study disinfection efficacy at the laboratory

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FIGURE 2
Schematic Diagram for Sequential Chlorination Bench-Scale Experiments

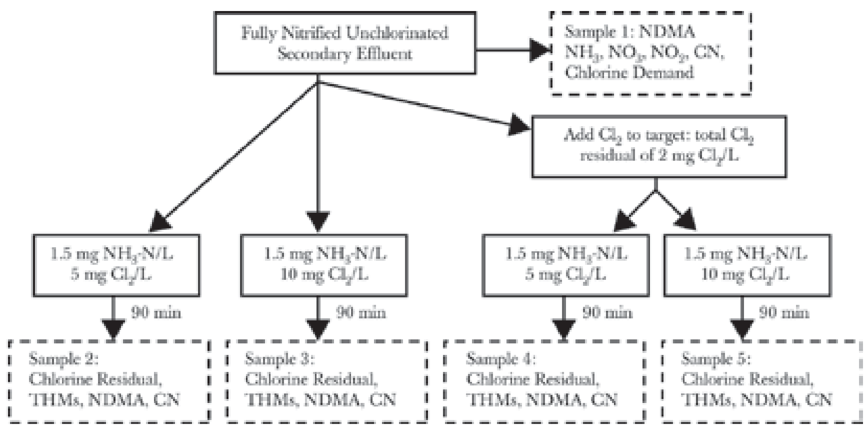

TABLE 2
Full-Scale Sequential Chlorination Testing: Facility Information

Test Facility	Test Period	Average Flow (MGD)	NDN Process
San Jose Creek East WRP	01/23/07 - 02/16/07	55	Step Feed
San Jose Creek West WRP	10/02/06 - 10/30/06	30	Step Feed
Whittier Narrows WRP	11/01/06 - 12/01/06	8	Modified Ludzack-Ettinger
Long Beach WRP	05/22/06 - 06/27/06	20	Step Feed

scale (Phase III) and pilot scale (Phase IV) with the specific goal of meeting California Title 22 virus inactivation requirements for "disinfected tertiary recycled water." Table 1 summarizes the specific objectives and scope of each phase of the study.

MATERIALS AND METHODS

Phase I: Laboratory Experiments on DBP Formation

The focus of the Phase I experiments was to determine DBP formation from sequential chlorination and compare that with DBP formation from chloramination. Specific DBPs evaluated included THMs, NDMA, and cyanide. Microbial analyses were not conducted in these bench-scale experiments. Fully nitrified secondary effluent samples from the Districts' Long Beach WRP were used for the experiments. The samples were disinfected by chloramination and sequential chlorination. Figure 2 shows the test plan, including the ammonia and chlorine doses, contact times, and the water quality parameters analyzed. This procedure was repeated five times to evaluate the consistency of the results.

Phase II: Plant-scale Testing on DBP Formation and Disinfection Efficacy

Plant-scale studies were conducted at several WRPs operated by the Districts. Table 2 summarizes the average flow treated and the type of nitrification/denitrification (NDN) processes employed at these WRPs.

Each plant was tested for several weeks during which extensive sample collection and analysis was conducted. Samples were analyzed for chemical parameters (ammonia, THMs, NDMA, and cyanide), microbial indicators (total coliform and enteric virus), and aquatic toxicity. For NDMA analysis, 24-hour composite samples were collected. All other samples were grab samples. Typically, two sets of samples were collected on a daily basis; secondary effluent samples were collected around 7:30 a.m. and 9:30 a.m., and chlorinated final effluent samples at 10:30 a.m. and 12:30 p.m. The time difference was to account for the hydraulic retention time in the filters and in the chlorine contact tanks. Samples were also collected immediately downstream of the media filters (filtered effluent samples) to evaluate disinfection efficacy of free chlorine added upstream of the filters.

Phase III: Laboratory Experiments on Disinfection Efficacy

It was not feasible to demonstrate high levels of virus inactivation (5 logs required by California regulations for "disinfected tertiary recycled water") by sequential chlorination at plant-scale because indigenous virus concentrations are usually lower than 10^5/0.1L in Districts' tertiary WRP secondary effluent, and it was not practical to seed the amount of virus needed for the demonstration. Consequently virus inactivation by the sequential chlorination process was studied initially at the laboratory scale. The experiments were conducted with fully nitrified secondary effluent samples collected from the San Jose Creek WRP. Two indicator viruses, MS2 coliphage and poliovirus, were seeded to the samples, and three disinfection schemes were tested:

1) Chlorination: to simulate the first step of sequential chlorination;
2) Chloramination: to simulate the second step of sequential chlorination; and
3) Sequential chlorination: to simulate overall sequential chlorination process with free chlorine addition followed by chloramines (ammonia then chlorine) addition.

In each experiment, a portion of the effluent sample was first analyzed to obtain the baseline water quality parameters as well as total coliform concentrations. The rest of the sample was seeded with poliovirus and MS2 coliphage, and thoroughly mixed for at least 20 minutes. After mixing, initial virus concentrations were determined by collecting an aliquot of the sample before any chlorine treatment. For the free chlorine experiments, chlorine was added to the sample. Chloramine experiments added ammonia followed by chlorine. The sequential chlorination experiments added chlorine first, followed by ammonia then more chlorine. At pre-determined contact times, total and/or free chlorine residuals were measured. Samples were then dechlorinated using sodium thiosulfate, and analyzed for viruses as well as total coliform.

Phase IV: Pilot-scale Testing of Virus Inactivation

To verify the results from the Phase III study, the Districts conducted pilot-scale testing on virus inactivation at the San Jose Creek WRP. Figure 3 is a schematic diagram of the pilot-scale chlorine contact system constructed for the study. The system included two channels with 1-foot by 1-foot cross-sections. The length of the channels varied by experiment, as described below. Baffles were installed near the inlet of each channel to provide uniform flow distribution. Tracer tests were performed prior to any virus testing to determine modal contact times corresponding to several test flow rates. During virus testing, the channels were covered, as are the full-scale chlorine contact tanks at the plant, to avoid any effects from sunlight, wind, or dust.

Two types of tests were conducted with nitrified secondary effluent. One tested virus inactivation by free chlorine alone and used a single 24-foot long channel with an effluent flow rate of 8 gallons per minute (gpm). The other tested sequential chlorination and used two channels; the first channel was 12 feet long, used a flow rate of 22 gpm, and was dosed with free chlorine, while the second channel was 36 feet long, used a flow rate of 6 gpm, and was dosed with chloramines. In both types of experiments, virus (M2 coliphage) was mixed into the effluent with a static inline mixer. Following mixing, a sample was collected for analysis of initial virus concentration.

For the free chlorine experiments, chlorine was added upstream of the channel, and mixed into the flow using static inline mixers. Free chlorine residuals were measured at all sampling points within the channel. Samples were collected at four points along the length of the channel (corresponding to four different contact times), dechlorinated, and delivered to the laboratory for virus analysis. For the sequential chlorination experiments, chlorine was also added upstream of the first channel. Ammonia was then added to the end of the first channel, followed by more chlorine addition upstream of the second channel to form chloramines (Figure 3). Free and/or total chlorine residuals were measured at selected locations in each channel. Samples were collected at the end of each channel, dechlorinated, and delivered to the laboratory for virus analysis.

FIGURE 3
Schematic Diagram of Pilot-Scale Chlorine Contact System

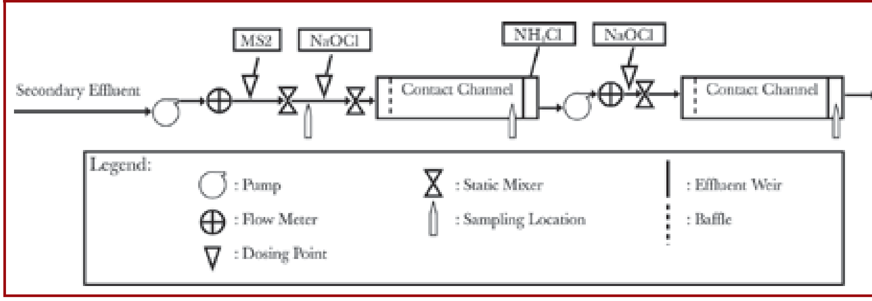

TABLE 3
Water Quality Data

	WRP[a]	Turbidity (NTU)	Ammonia Nitrogen (mg N/L)	Nitrate Nitrogen (mg N/L)	Nitrite Nitrogen (mg N/L)	Chlorine Demand (mg/L)
Phase I: Laboratory	LB	—	0.4 ± 0.3	5.2 ± 2.7	0.22 ± 0.20	—
Phase II: Full-Scale	LB	1.1 ± 0.1	<1[b]	5.6 ± 0.7	0.02 ± 0.01	—
	SJCE	2.0 ± 0.8	1.2 ± 0.6	2.2 ± 0.9	1.30 ± 0.40	—
	SJCW	1.4 ± 0.4	<1[b]	6.1 ± 1.1	0.09 ± 0.03	—
	WN	1.6 ± 0.6	<1[b]	7.2 ± 1.0	0.02 ± 0.00	—
Phase III: Laboratory	SJCE & SJCW	1.0 ± 0.3	0.2 ± 0.1	2.0 ± 1.2	0.06 ± 0.03	3.9 ± 0.5
Phase IV: Pilot-Scale	SJCW	0.8 ± 0.2	<0.10[c]	4.0 ± 1.2	0.05 ± 0.01	3.4 ± 0.4

—: Not measured.
[a]Abbreviations: LB: Long Beach. SJCE: San Jose Creek East. SJCW: San Jose Creek West. WN: Whittier Narrows.
[b]All ammonia samples from LB, SJCW, and WN during Phase II had concentrations below the reporting limit of 1 mg N/L; ammonia analysis in Phases III and IV had a lower reporting limit (0.10 mg N/L).
[c]14 samples were below the reporting limit of 0.10 mg N/L; one sample had an ammonia concentration of 0.13 mg N/L.

WATER QUALITY

Table 3 provides water quality data for the secondary effluents used in this study. During Phase II at the full-scale plants, water quality samples were not taken specifically for this project; data in Table 3 were taken from routine monitoring samples for process control. During Phase III, some samples were taken in the morning when the effluent flow through the WRP was low and some samples were taken at noon (high flow); no performance differences were observed, so the data were combined for this paper. For Phases III and IV, pH values were also measured, with values of 7.2 ± 0.2 in both phases.

MIXING AND SAMPLING

The rate at which chlorine is mixed into the effluent may affect disinfection efficacy and DBP formation. Consequently, mixing in the laboratory,

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TABLE 4
Results of Bench-scale Study to Evaluate DBP Formation

Sample Number	Sample Description	Chlorine Residual (mg/L)	Cyanide (µg/L)	Total THMs (µg/L)	NDMA (ng/L)
1	Unchlorinated Secondary Effluent	—	<5	—	100 - 140
2	Chloramination	2.8 - 3.3	<5	3 - 5	300 - 1,300
3	Chloramination	4.6 - 5.8	<5	7 - 11	1,100 - 5,400
4	Sequential Chlorination	3.4 - 7.0	<5	56 - 65	110 - 230
5	Sequential Chlorination	0.5 - 3.0	<5	63 - 72	100 - 200

TABLE 5
Comparison of NDMA Concentrations in Chlorinated Effluents

Test Facility	Chloramination			Sequential Chlorination		
	No. of samples	NDMA (ng/L)		No. of Samples	NDMA (ng/L)	
		Range	Median		Range	Median
San Jose Creek East WRP	34	1,000 - 5,000	2,050	18	200 - 590	310
San Jose Creek West WRP	28	400 - 3,700	985	21	260 - 650	440
Whittier Narrows WRP	28	52 - 850	320	17	37 - 590	160
Long Beach WRP	21	500 - 3,200	1,400	30	93 - 880	425

TABLE 6
Total Coliform Results from Full-Scale Chlorination Testing

Test Facility	Filtered Effluent (After Free Chlorine)		Final Effluent (Sequential Chlorination)	
	No. of Samples	Total Coliform (CFU/0.1 L)	No. of Samples	Total Coliform (CFU/0.1 L)
San Jose Creek East WRP	19	1 - >200	19	<1 - 2
San Jose Creek West WRP	28	<1 - 115	21	<1 - 1
Whittier Narrows WRP	13	1 - 400	15	<1 - 2
Long Beach WRP	22	<1 - 2	26	<1 - 1

pilot, and full-scale systems was evaluated through the calculation of the product Gt, where G is the velocity gradient and t is the mixing time. The Gt values for the three systems were of the same order of magnitude (calculations not shown), indicating that the mixing should be similar across the systems; the full-scale system had slightly better mixing, with Gt values 1-3 times higher than at laboratory or pilot-scale.

Samples for NDMA, THMs, and microbial analyses were collected in amber glass jugs, amber glass vials, and sterilized plastic containers, respectively. Plastic containers were used for other samples. Samples for microbial and NDMA analyses were dechlorinated by adding sodium thiosulfate in the sample containers.

Samples for THM analysis were first quantitatively dechlorinated and then poured into the sample vials. The quantitative dechlorination procedure avoided over-dechlorination, which may damage the analytical instrument.

CHEMICALS AND MICROORGANISMS

Chlorine was applied as sodium hypochlorite. Sodium hypochlorite, 4-6% by weight (Fisher Scientific, Pittsburgh, PA), was diluted to different strengths and standardized in the laboratory for each bench and pilot scale experiment. For bench scale experiments, ammonia standard (1,000 mg NH_3-N/L) obtained from Environmental Resource Associates (Arvada, CO) was used as received.

Ammonia solutions used for pilot-scale experiments were made in the laboratory using ammonium chloride powder (99.5% purity) from EMD Chemicals (Gibbstown, NJ). MS2 coliphage (American Type Culture Collection #15597B1) was purchased from GAP EnviroMicrobial Laboratory in Canada. Poliovirus was cultured in the Districts' Microbiology Laboratory, using CHAT type-1 poliovirus (American Type Culture Collection #VR192, a predecessor to the currently available #VR1562).

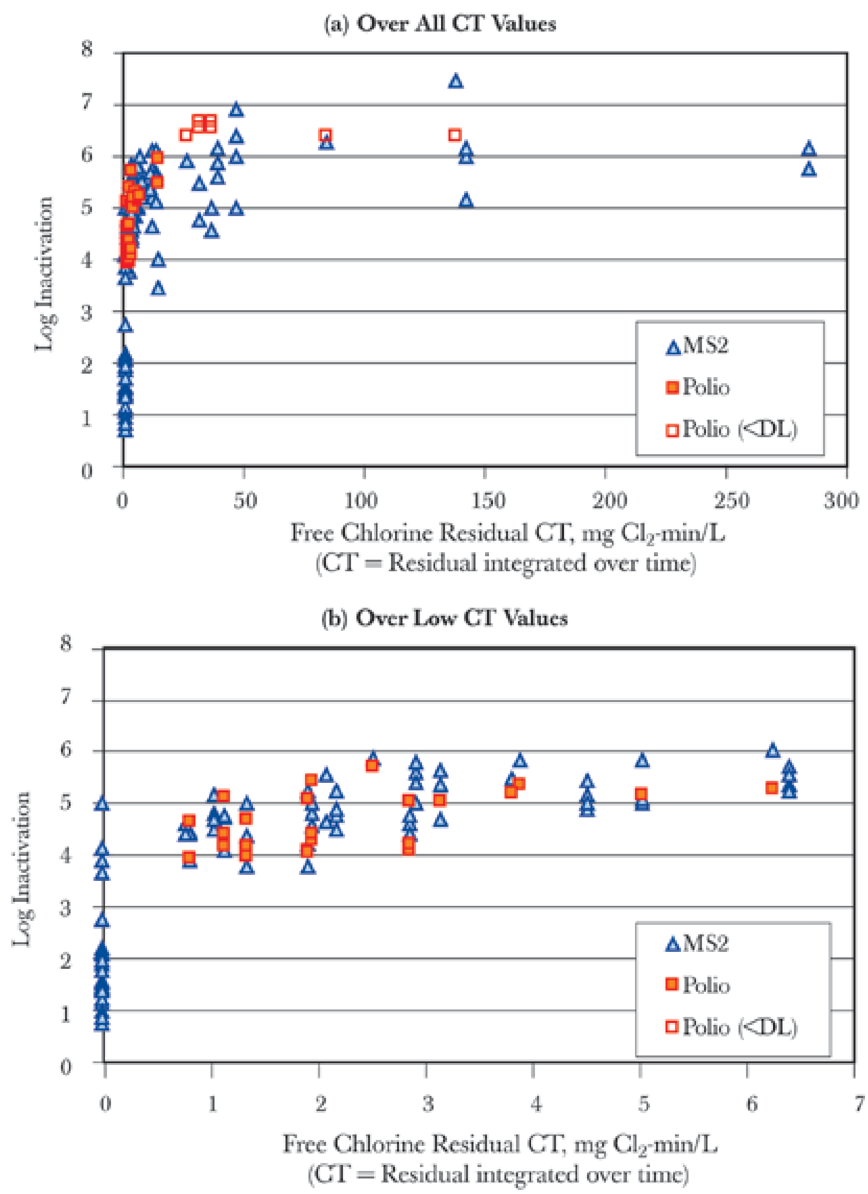
LABORATORY ANALYSES

The Districts' laboratories conducted all chemical analyses for this project, and are certified by the California Department of Public Health for these analyses. NDMA analysis used EPA Method 1625, which employs liquid-liquid extraction followed by chemical ionization isotope dilution gas chromatography/mass spectrophotometry; the reporting limit is 2 nanograms per liter (ng/L) in secondary and final effluent samples. THM analysis used EPA Method 8260 and the reporting limit for each THM species is 2 microgram per liter (µg/L). Free and total chlorine residuals were measured using a colorimeter test kit manufactured by Hach Company (Loveland, Colorado). Free chlorine analysis used EPA-approved Alternative Method 8021, with a factory-reported detection limit of 0.02 mg Cl_2/L. Chloramine analysis used EPA approved Alternative Method 8167, with a factory-reported detection limit of 0.1 mg Cl_2/L. Total cyanide measurements were conducted using the Midi Distillation System followed by manual colorimetric analysis [EPA 335.4, Standard Method 4500-CN-C (American Public Health Association, 1998)]. The method detection limit is 1 µg/L, and laboratory reporting limit is 5 µg/L.

For enteric virus, the laboratories adapted the procedure described in EPA's *Manual of Methods for Virology* for sample collection and concentration; Standard Methods 9510 C and 9510 G were used for poliovirus quantification. The reporting limit of enteric viruses is typically 0.001 IU (infectious unit) per liter. The detection limit for poliovirus analysis depends on the sample volume. EPA Method 1601 was used to measure the concentration of MS2 coliphage. The typical detection limit is 2 MPN/0.1L. Total coliform analysis used Standard Method 9222B, a membrane filter (MF) procedure. The MF method was chosen because the membrane filter technique is highly reproducible and usually yields numerical results more rapidly than the multiple-tube fermentation procedure (American Public Health Association, 1998). The detection limit for the MF method is 1 colony forming unit (CFU)/0.1 L.

Chronic toxicity testing was conducted using concurrently collected secondary effluent (prior to chlorine addition) and final effluent (disinfected) samples. Tests were conducted on *Pimephales promelas* and *Ceriodaphnia dubia* and followed procedures described in *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms* (EPA, 2002). Potential chronic toxicity as a result of sequential chlorination was determined by comparing survival and sub-lethal effects on the two test organisms in secondary effluent samples versus those in disinfected final effluent samples.

FIGURE 4
Laboratory Experiment Results of Virus Inactivation by Free Chlorine



RESULTS AND DISCUSSION

Phase I

As indicated in Table 4, sequential chlorination resulted in significantly reduced NDMA levels (100 – 230 ng/L), as compared to the levels from chloramination (300 – 5,400 ng/L). Sequential chlorination resulted in higher total THM concentrations; however, these concentrations were below the drinking water standard for total THMs, 80 µg/L. Neither chloramination nor sequential chlorination generated cyanide concentrations above the laboratory reporting limit.

Phase II

Because the laboratory DBP results were promising, the Districts tested the sequential chlorination process at several of their WRPs. Operating conditions were as follows: chlorine dose added to nitrified secondary effluent was typically 5 mg Cl_2/L. This chlorine dosage exceeded chlorine demand of the secondary effluent and resulted in approximately 1 mg Cl_2/L of total chlorine residual. Following filtration, ammonia was dosed at approximately 1 mg N/L. Chlorine was then added at a chlorine to ammonia nitrogen mass ratio of approximately 5:1 to form chloramines, which resulted in approximately 4.5 mg Cl_2/L of total chlorine residual immediately after chlorine addition.

Table 5 compares the NDMA concentrations in the final effluent under chloramination (historical data, 2004 – 2006) and sequential chlorination. The table shows that sequential chlorination yielded much lower NDMA concentrations at all four WRPs. Reduction of median NDMA concentrations ranged from 160 ng/L (~50%) at Whittier Narrows WRP to 1,740 ng/L (~85%) at San Jose Creek East WRP. The extent of NDMA reduction appeared to be related to the polymer doses.

FIGURE 5
Laboratory Experiment Results of Total Coliform Inactivation by Free Chlorine

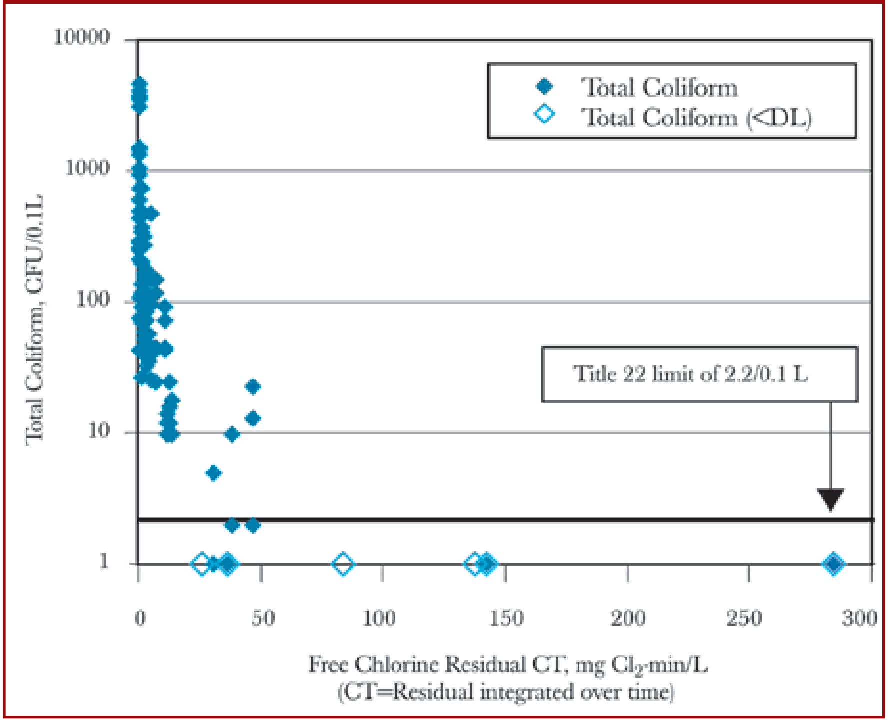
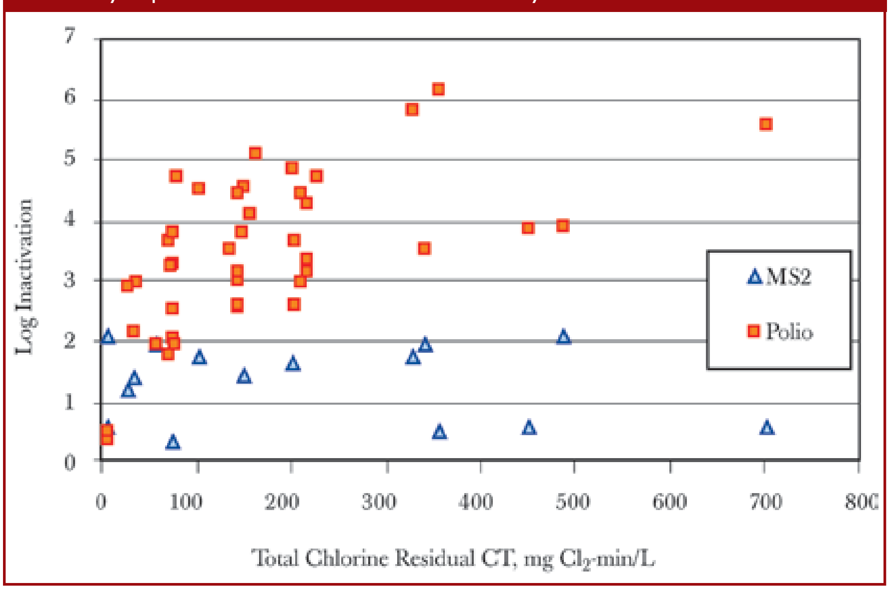


FIGURE 6
Laboratory Experiment Results of Virus Inactivation by Chloramines



Among the WRPs tested, the Whittier Narrows WRP used the least amount of polymer, had the lowest NDMA concentrations under chloramination, and experienced the smallest reduction in NDMA concentrations with sequential chlorination.

As expected, total THM concentrations were higher under sequential chlorination. Out of 161 samples analyzed during the sequential chlorination testing, the total THM concentrations ranged from 7.0 to 75 µg/L; median concentration was 35 µg/L. These levels were well within the drinking water standard, 80 µg/L. Out of 162 samples collected for cyanide analysis, all but two samples (from the same WRP; the highest value was 9 µg/L) had concentrations below the laboratory reporting limit of 5 µg/L.

Table 6 summarizes the total coliform results from the Phase II study. Typical total coliform concentration in unchlorinated secondary effluents is approximately 10^4/0.1 L. Free chlorine and filtration reduced total coliform concentrations by at least two to three orders of magnitude. However, the filtered effluent total coliform levels could still exceed the California Title 22 standard of 2.2/0.1 L for unrestricted reuse (except at the Long Beach WRP). The total coliform concentrations after subsequent chloramination, however, were consistently in compliance with the standard. At the Long Beach WRP, three filtered effluent samples were collected and analyzed for indigenous enteric virus. None of the samples detected enteric virus (detection limit = 0.001 IU/L).

A total of 14 sets of secondary and chlorinated final effluent samples (final effluent samples were dechlorinated in the laboratory) were collected for chronic toxicity testing. The results indicated no aquatic toxicity resulting from sequential chlorination.

In summary, the Phase II study results confirmed that sequential chlorination reduced the formation of NDMA while maintaining acceptable levels of THMs and cyanide, meeting Title 22 total coliform requirements, and producing no aquatic toxicity to the receiving water.

Phase III Chlorination Experiments

Free chlorine disinfection was tested on 16 fully nitrified secondary effluent samples collected from the San Jose Creek WRP. Chlorine doses were between 1.5 and 10 mg Cl_2/L, contact times were between 1 and 90 minutes. Free chlorine residual CT values were calculated by integrating free chlorine residual concentration over contact time. Figures 4(a) and 4(b) show MS2 and poliovirus inactivation results with free chlorine for all CT values and for low CT values, respectively. Points with a zero CT value represent conditions in which free chlorine residual was not detected, i.e., when chlorine doses were lower than the chlorine demand.

Free chlorine generally inactivated

MS2 and poliovirus to a similar degree. Most disinfection occurred at or shortly after the time that free chlorine was added (Figure 4(b)). For CT values ≥ 1 mg Cl_2-min/L, MS2 inactivation was ≥ 4-log in 96% (78 of 81) of the samples and poliovirus inactivation was ≥ 4-log in 97% (29 of 30) of the samples. As CT increased above 1 mg Cl_2-min/L, MS2 disinfection increased slowly and leveled off at approximately 6-log inactivation. Poliovirus disinfection also increased slowly as CT increased above 1 mg Cl_2-min/L, but could not be quantified, because poliovirus concentrations in treated samples were below the detection limit (DL).

Inactivation of total coliform was also evaluated. At CT values above 50 mg Cl_2-min/L, disinfection of total coliform consistently met the Title 22 requirement, as indicated in Figure 5.

Chloramination Experiments

The chloramination step of sequential chlorination was tested on 16 fully nitrified secondary effluent samples collected from the San Jose Creek WRP. These samples were dosed with 1 to 3 mg N/L followed by 5 to 10 mg Cl_2/L. The dosed chlorine to ammonia nitrogen mass ratio ranged from 3.3 to 5.3 mg Cl_2/mg N, and contact times ranged from 1 to 90 minutes. The total chlorine residual CT values, ranging from 6 to 774 mg Cl_2-min/L, were calculated as the product of total chlorine residual and contact time. As shown in Figure 6, chloramines were clearly weaker disinfectants than free chlorine, and yielded lower inactivation values for both microorganisms, especially MS2 coliphage. Disinfection of poliovirus generally increased with total chlorine residual CT values, but MS2 coliphage was resistant to chloramines. Little or no improvement in disinfection performance was observed with increasing CT values.

Chloramines effectively disinfected total coliform, as indicated in Figure 7. Total coliform concentration was consistently below the Title 22 requirement at CT value above approximately 100 mg Cl_2-min/L.

FIGURE 7
Laboratory Experiment Results of Total Coliform Inactivation by Chloramines

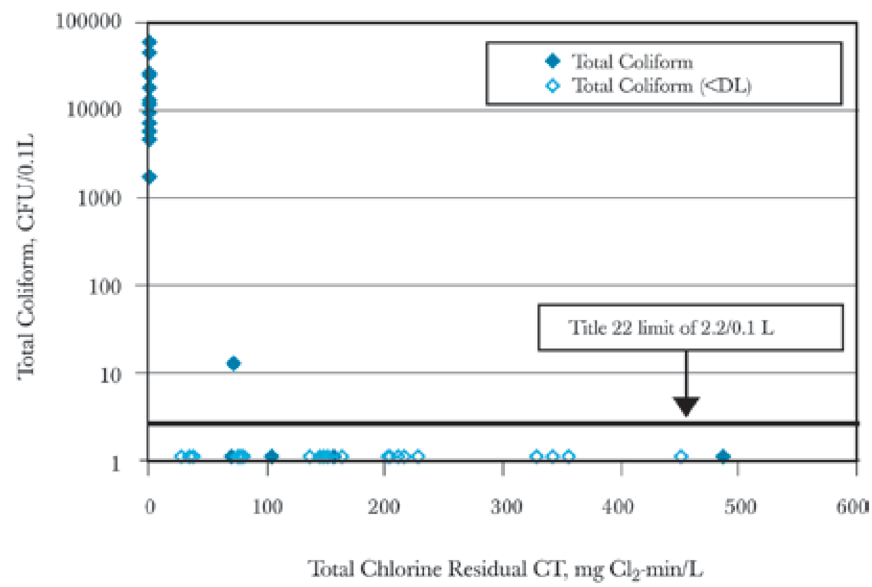
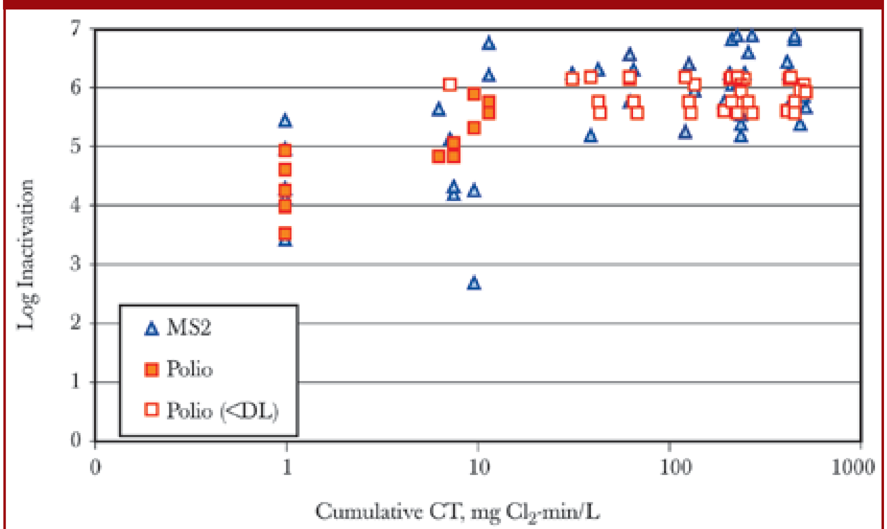


FIGURE 8
Laboratory Experiment Results of Virus Inactivation by Sequential Chlorination



Sequential Chlorination Experiments

Eight experiments were conducted to evaluate the total virus inactivation by sequential chlorination, in which samples were disinfected in two steps. In the first step, 5 to 5.5 mg Cl_2/L of sodium hypochlorite was added to the samples for contact times up to 10 minutes (free chlorine residual CT values between 1 and 10 mg Cl_2-min/L). Ammonia was then added and followed by additional hypochlorite, to form chloramines. Ammonia doses were 0.5 to 1.5 mg N/L, hypochlorite doses were 2.5 to 5.0 mg Cl_2/L, and the dosed chlorine to ammonia mass ratio ranged from 3.3 to 5.0 mg Cl_2/mg N. Chloramine contact times were between 1 and 90 minutes. The cumulative CT values, ranging from 6 and 541 mg Cl_2-min/L, were calculated as the sum of the free chlorine CT value and the total chlorine residual CT value from chloramination.

Virus inactivation results from the sequential chlorination process are shown in Figure 8. In most cases, the first step of sequential chlorination (free chlorine) achieved >4-log inactivation of both MS2 and poliovirus, consistent

FIGURE 9
Laboratory Experiment Results of Total Coliform Inactivation by Sequential Chlorination

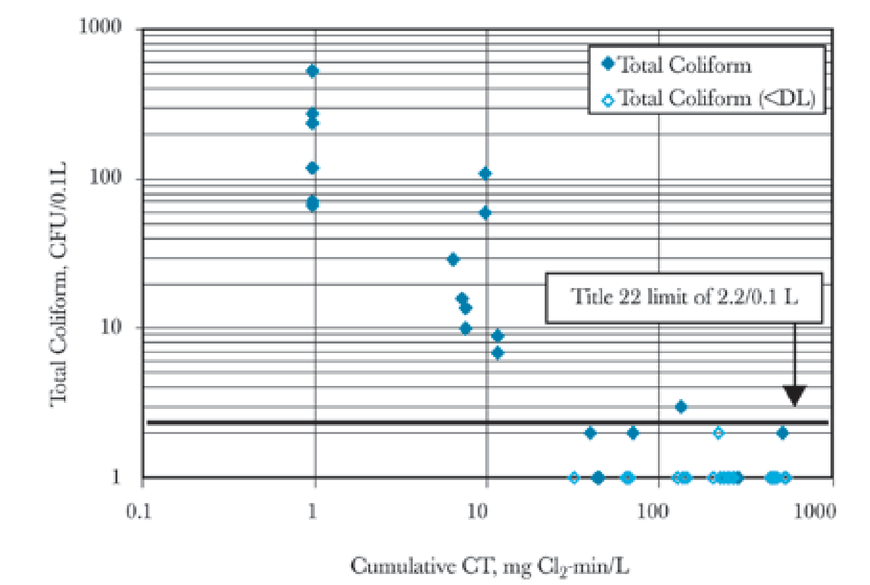
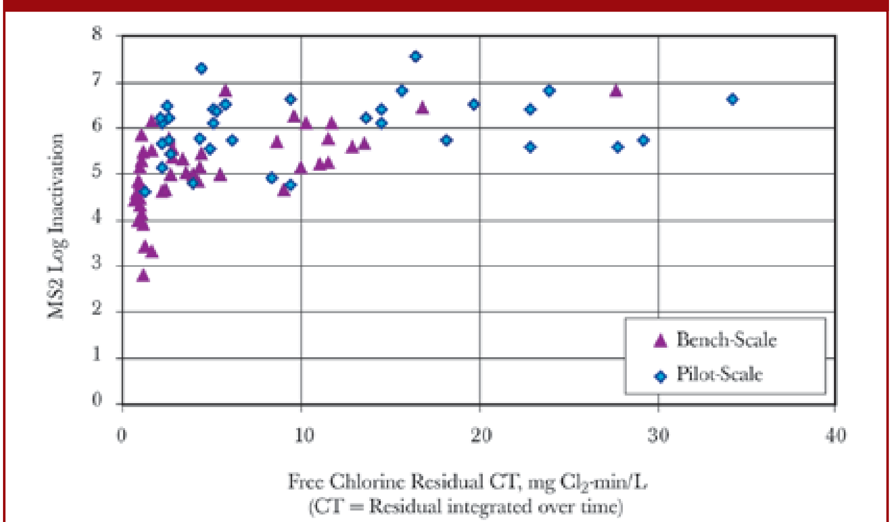


FIGURE 10
Pilot Testing Results of MS2 Coliphage Inactivation by Free Chlorine Only



with results from the free chlorine experiments discussed above. In the few cases that free chlorine did not achieve >4-log inactivation, subsequent chloramination provided additional disinfection. As indicated in Figure 8, inactivation of both poliovirus and MS2 was >5-log in all cases where the cumulative CT value was greater than 15 mg Cl_2-min/L. Beyond this CT value, virus inactivation was not strongly affected by the cumulative CT value. Poliovirus levels were below detection following chloramine addition. MS2 is resistant to chloramines, so additional chloramine contact time has insignificant effect on its inactivation.

Total coliform was also measured in these experiments; results are shown in Figure 9. Total coliform levels decreased rapidly up to a cumulative CT value of 15 mg Cl_2-min/L. Above a cumulative CT value of 30 mg Cl_2-min/L, total coliform levels were <2.2/0.1 L in 31 of 32 samples.

Phase IV

Ten experiments were conducted to test free chlorine disinfection of seeded virus in the pilot-scale contactor. Free chlorine doses ranged from 3.7 to 5.8 mg Cl_2/L, and the modal contact times ranged from 2 to 10 minutes (based on tracer test results); free chlorine residual CT values were calculated by integrating free chlorine residual concentration over contact time. As shown in Figure 10, free chlorine alone, the first step of the sequential chlorination process, achieved >5-log MS2 inactivation in all but four samples. The minimum MS2 inactivation observed was 4.6-log. These results were consistent with those obtained from the bench-scale experiments (also plotted in Figure 10 for comparison).

Five experiments were conducted to test the overall sequential chlorination disinfection of seeded virus in the pilot-scale contactor. In the first channel, chlorine doses ranged from 4.1 to 4.3 mg Cl_2/L, and the modal contact time was approximately 2.4 minutes (based on tracer test results). The cumulative CT values were calculated as the sum of the free chlorine CT value (calculated by integrating free chlorine residual concentration over contact time) and the total chlorine residual CT value from chloramination (calculated as the product of total chlorine residual and contact time). At the end of the first channel, ammonium chloride (1.1 to 1.2 mg N/L) was added to stop free chlorine reaction. Then, at the beginning of the second channel, more chlorine (3.6 to 5.5 mg Cl_2/L) was applied to form chloramines. Samples were collected at the end of each channel for virus analysis.

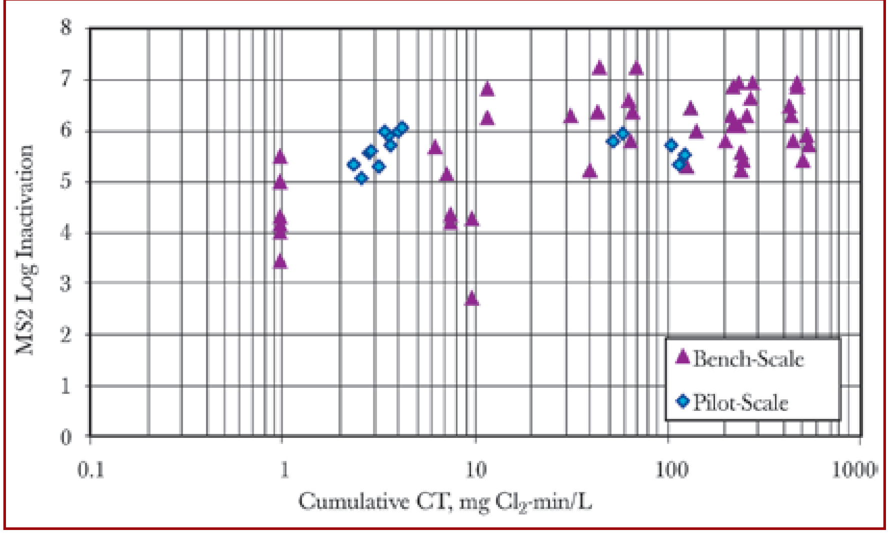
Figure 11 shows the results from these experiments. Free chlorine, the first step of sequential chlorination, achieved >5-log MS2 inactivation; the chloramines added in the second step had a marginal effect on MS2 inactivation. These results were in general agreement with those obtained from the bench-scale experiments, also plotted in Figure 11 for comparison.

CONCLUSIONS

The sequential chlorination process is a new approach for disinfection of fully nitrified effluent produced by wastewater treatment and reclamation facilities. The process can be implemented using existing chloramination infrastructure with minor modifications. Plant-scale testing results have shown that the process significantly reduces NDMA formation in comparison to chloramination. By lowering the NDMA levels in the recycled effluent, sequential chlorination could help save the costs of downstream advanced oxidation process for NDMA removal in indirect potable reuse applications. The process does result in a moderate increase in THM formation, but the levels of total THMs are well below the drinking water standards. Sequential chlorination generates insignificant amounts of cyanide and does not cause aquatic toxicity.

Because of the use of free chlorine, the sequential chlorination process is more efficient than chloramination with respect to pathogen inactivation. Sequential chlorination can achieve the same level of pathogen inactivation as chloramination, but with a much shorter chlorine contact time. This could lead to savings in chlorine contact tanks construction for new projects, creation of available space in existing chlorine contact tanks for other uses (e.g., storage, flow equalization), or an increase in treatment capacity.

FIGURE 11
Pilot Testing Results of MS2 Coliphage Inactivation by Sequential Chlorination



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