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ENVIRONMENTAL ENGINEER

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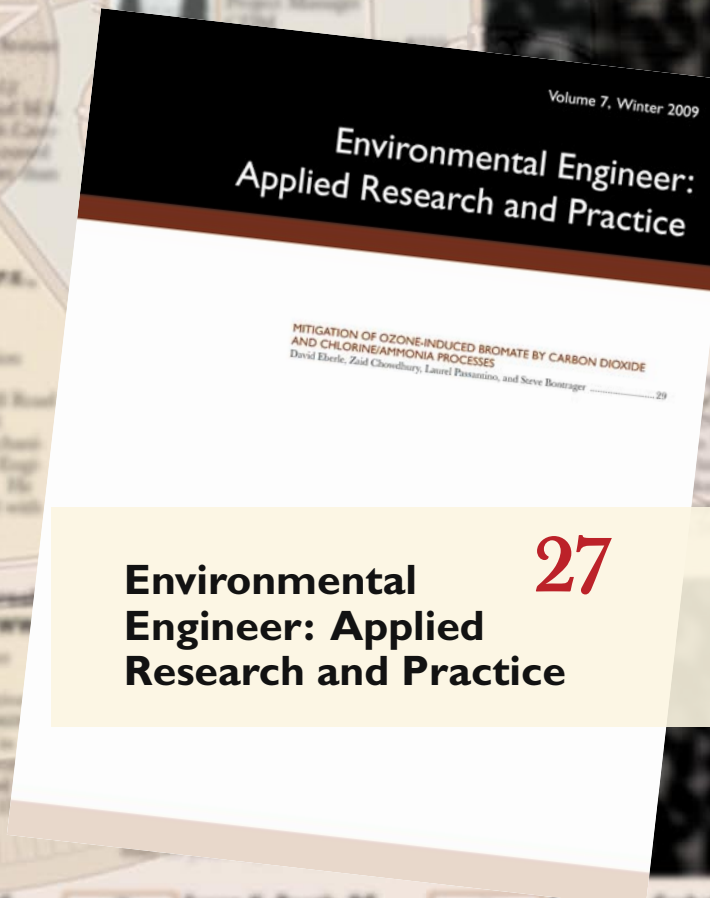
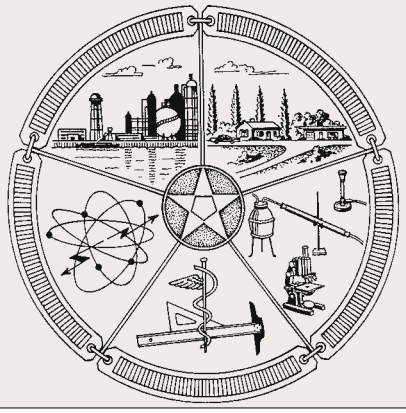


ENVIRONMENTAL ENGINEER



ENVIRONMENTAL ENGINEER:
APPLIED RESEARCH AND PRACTICE

AAEE's professional journal.

BY DEBRA R. REINHART, PH.D., P.E., BCEE

10 CATALYSTS FOR SUCCESS

THANKS FOR TAKING THE TIME TO READ MY INAUGURAL MESSAGE TO YOU AS PRESIDENT OF AAEE. First, I want to thank Bill Dee for his great service to AAEE this past year as president. His thoughtful leadership has positioned AAEE to make a global impact in the near future.

When I was inducted as your President at our Annual Installation Dinner this past November, I noted how this is a great time to be taking office. I even listed ten reasons for my optimism and I would like to share with you, in an abbreviated form, why I am excited about AAEE today.

Reason No. 1: Environmental Engineering plays a critical role in global health and well being today. Last year, the National Academy of Engineering identified 14 grand challenges for engineering; meeting four of them requires the innovation and insight unique to environmental engineers. These are daunting tasks, but ones I am confident you, as AAEE members, will help solve.

Reason No. 2: Because of the attention that is being paid to issues such as global warming, the enrollments in environmental engineering education programs are increasing. Through our Tau Chi Alpha Chapters and new student membership, we will be in an excellent position to serve this growing number and encourage these students to become life-long learners as they move through licensure and certification.

Reason No. 3: ABET recently approved a significant change in its procedures and now allows universities to accredit similarly named academic programs at the BS and MS levels. While implementing these changes still has some challenges, this is very important to environmental engineering. Many of our BCEEs and BCEEMs have Environmental Engineering degrees only at the MS level. In addition, I believe a BS is not sufficient to meet our future technical challenges. Accreditation at both levels will help ensure that those programs meet our high standards and educational needs.

Reason No. 4: As part of our strategic planning efforts, we are expanding our presence internationally. This will bring greater prestige to our organization and serve expanding needs in a global economy.

Reason No. 5: In order to improve service to you, we have developed an excellent strategic plan under the leadership of Brian Flynn. That strategic plan has identified critical needs in financing, membership services, diversification, outreach, and education. This strategic plan will guide me through my year as President, and ensure that efforts we make in governing the Academy best suit your needs.

Reason No. 6: Thanks to the efforts of our former Executive Director, Larry Pencak, our treasurer Christian Davies-Venn, Steve Kellogg for his Campaign 4000, and our dedicated membership the Academy is in its best financial state in years.

Reason No. 7: We have seen growth in AAEE membership and retention over the past few years. A few reasons for this growth are that we have identified your needs and interests through surveys, made new contacts at major conferences, and expanded our numbers through our eminence program.

Reason No. 8: In the next several months, the Environmental Engineering Body of Knowledge will be published. This Body of Knowledge defines the knowledge and core competencies integral to the understanding and practice of environmental engineering. I believe it will provide important guidance and input to everyone involved in educating environmental engineers and ensure that future environmental engineers have the knowledge and ability necessary to meet professional challenges.

Reason No. 9: I am so grateful to the many, many volunteers who make it possible to govern the Academy with our lean budget. Those of you who give tirelessly to the Academy will make my tenure as President so much easier.

Reason No. 10: Here you will have to allow me a personal digression to remember the late Dr. Fred G. Pohland, my mentor and academic advisor at Georgia Tech. He was one of the original AAEE members and a Past President. Fred's devotion to the Academy inspired me to become certified. I will always be grateful to him.

So, I look forward to a busy, productive year. Please let me know if you have ideas, concerns, or want to volunteer. You can find my contact information in the *Who's Who in Environmental Engineering!*

ENVIRONMENTAL ENGINEER

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DISTINGUISHED ENGINEERS RECOGNIZED

The Academy will recognize five distinguished environmental engineers at its Awards Luncheon to be held at the National Press Club in Washington, DC on Wednesday, May 6, 2009:

Thomas E. Wilson, Ph.D., P.E., BCEE
Gordon Maskew Fair Award

Stephen P. Graef, Ph.D., P.E., BCEE
Stanley E. Kappe Award

Walter J. Bishop, P.E., BCEE
Edward J. Cleary Award

Dr. Perry McCarty
Honorary Board Certified Environmental Engineer

Michael J. Rouse
Honorary Board Certified Environmental Engineer

Tickets for the Luncheon are $65.00 and can be ordered from Academy Headquarters now. You can use the flyer at http://www.aaee.net or call the Academy at 410-266-3311; MasterCard and VISA are accepted.

EXCELLENCE IN ENVIRONMENTAL ENGINEERING

Thirty-four entries were received for 2009. The entries cover projects and programs in:

Research -- 3
University Research -- 3
Planning -- 3
Small Projects -- 2
Design -- 20
Small Firms -- 2
Operations/Management -- 1

The entries will be judged by an independent panel of experts electronically. The winning panels will be displayed during the Academy's 2009 Awards Luncheon on Wednesday, May 6.

SUSTAINABILITY CERTIFICATION

The Academy is considering adding a new specialty certification on sustainability.

Brian Flynn, Academy Vice President, is leading this effort. He is currently forming a work group that will better define the certification and its required competencies. This is the run-up to developing an exam and getting the certification rolled out to our members.

The Sustainability Work Group needs volunteers. If you have experience with any of the following: sustainability, climate change, carbon footprints and offsets, green building, environmental impacts from energy sources, etc. and are willing to help, please contact Brian at 303-521-1611 or BFlynn4290@aol.com.

❖ ***Continued on 14*** ❖

BY JOSEPH S. CAVARRETTA, CAE

NEVER WASTE A GOOD CRISIS

AS WE RIDE THE DUSTY PLAINS OF ECONOMIC RECESSION, choking on the heels of investment and banking failures and outright fraud and theft in unprecedented proportions, we are relentlessly bombarded by news of global climate change, the Great Pacific Garbage Patch, terrorism threats and new insurgencies, contaminated foods, aging infrastructure, and more.

We are in one serious crisis, America. Because of its complexities, it may comprise the most serious permutation of challenges that America has ever faced. Conversely, Americans are tough enough to overcome these challenges. Even now, we are slapping the dust off our shoulders and gearing up to build a stronger America. We will rebuild America. We will solve our nation's woes. We will lead solutions to environmental problems globally. We'll do it sooner than anyone predicts. The worst will soon be over if it is not already over.

Truly, engineers and engineering professionals – especially environmental practitioners, have unprecedented opportunities to become the kinds of heros and global champions for which America is historically famous and whom we implicitly trusted.

Speaking of trust, do these names sound familiar? DeLorean, Paine Webber (aka UBS), Aldelphia, EF Hutton (scooped up by Lehman Brothers then CitiGroup), Drexel Burnham Lambert (Michael Milken), MCI World Com, Standard Oil, Enron, Arthur Andersen (Enron's Auditor)? How about JP Morgan, Merrill Lynch, Bear Stearns, Freddie Mac, Fannie Mae, Citibank, AIG, Lehman Brothers. What about names such as Bernard Madoff? While it may not be fair to lump all of the above into one paragraph, the point is one only has to read the names to understand why a big lack of trust exists today in America. No profession, including environmental engineering, can afford to follow a parallel path, not if we want America to remain a world leader.

TRUST BUT VERIFY

Building trust is vital to solving our problems. Everyone is on the lookout for bad players. The whole world is watching. We must build trust in our institutions, trust in business, trust in our values, trust in our partnerships, and trust among our neighbors. Transparency is paramount. For environmental practitioners to become America's superheros and global champions–to achieve meaningful success, we will need to demonstrate consistent core business ethics and practices, verify our expertise, and create groundbreaking success on new frontiers.

More than ever, American industries and professionals are under Grassroots America's microscope. Nothing does more to "Trust but Verify" than certification. While even the best credentials will not prevent a bad player from being bad, they surely help reduce the risk and virtually guarantee certain levels of expertise. Professional licensure and AAEE's BCEE/Diplomate (and the more recent BCEEM) designation, are examples of historical certifications attesting to excellence in practice. No question, many non-certified engineering practitioners and educators are extremely well qualified and may not feel a need to seek licensing or certification. But in this fast-paced world, credentials are the quickest way to begin the process of trust and verification. Certifications are to professional practice as trees and shrubs are to soil: They help to prevent erosion.

Of course, without industry support, credentials lose their brand value, which decreases demand. With fewer credentialed professionals, the risk of erosion dramatically increases. More bad players begin competing for limited projects, promising the impossible at fire-sale prices. Financially strapped clients might take the bait, projects fail, industry reputation is damaged, and everyone loses. That is how Bernard Madoff managed to carry on his Ponzi scheme. Few felt qualified to challenge his practices. This is why it is incumbent upon everyone in all fields and industries to support the growth and perpetuation of certifications. This is why AAEE was created 55 years ago by expert environmental engineers and sponsored by some of the most important engineering associations in America: *To provide a measure of verifiable expertise in specialty areas of environmental engineering.*

Environmental engineers and practitioners are gearing up to meet and mitigate the potentially catastrophic challenges of the 21st Century. They will be combining existing methodologies with state-of-the-art technologies to pioneer new solutions. Keep in mind the value and role that certification will play, not only in building trust with your partners, clients, and grassroots America, but also as a reliable verification of your own organization's competencies. A

GEORGE E. KURZ, P.E., BCEE, led the "Sewer Rehabilitation Strategy Workshop" at the 15th Underground Construction Technology (UCT) International conference & Exhibition, held January 19, 2009, in San Antonio, Texas. Mr. Kurz is currently Senior Technical Leader with Barge Waggoner Sumner and Cannon, Inc. He has been certified in Water Supply and Wastewater Engineering since 1995.

WALTER R. NIESSEN, P.E., BCEE, was presented with the 2008 American Society of Mechanical Engineer's Pioneer Award at the 27th Annual International Conference on Thermal Treatment Technologies, held in May 2008 in Montreal, Canada. Mr. Niessen is currently President of Niessen Consultants. He is a Life Member who has been certified in both Air Pollution Control and Solid Waste Management since 1974.

KIRANKUMAR "KUMAR" TOPUDURTI, PH.D., P.E., BCEE, won the 2008 Illinois Government Engineer of the Year Award, presented at the Illinois Society of Professional Engineers Annual Meeting this past July 2008. He also won the National Society of Professional Engineer's 2009 Federal Engineer of the Year Award, which was presented at the 30th Annual FEYA Banquet this past February. Dr. Topudurti, Deputy Director of the US Army Engineer R&D Center, has been certified in Hazardous Waste Management since 1997.

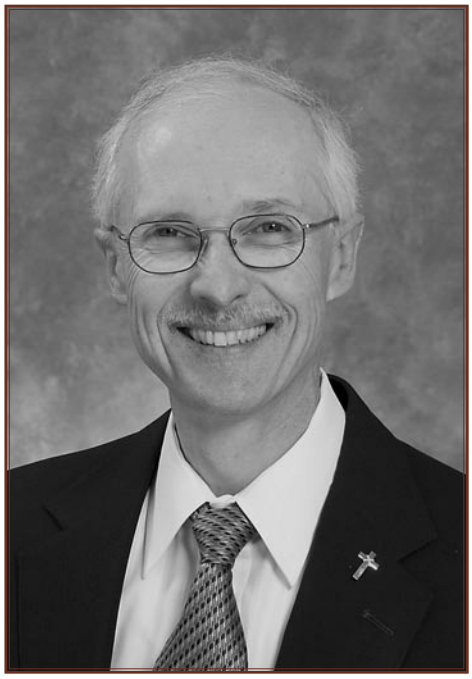
HILLEL SHUVAL, D.SC., P.E., BCEE, received the Award for Life Work Accomplishments in Protecting the Environment. He was presented with this award by Minister of Environmental Protection, Gidon Ezra, and the President of Israel, Mr. Shimon Peres, at a ceremony this past September 2008. Dr. Shuval is currently Head of the Department of Environmental Health Sciences for Hadassah Academic College-Jerusalem and Kunen-Lunenfeld Emeritus Professor of Environmental Sciences for The Hebrew University of Jerusalem. He is a Life Member and has been certified in Water Supply and Wastewater Engineering since 1980.

IN MEMORIAM

PETER A. KRENKEL, PH.D., P.E., BCEE, has passed away in June 2008. Dr. Krenkel was Professor and Dean Emeritus of the College of Engineering at the University of Nevada Reno. He was a Life Member and had been certified in Water Supply and Wastewater Engineering since 1975.

THOMAS E. VIK, P.E., BCEE, passed away in November 2008. Mr. Vik was Senior Vice President and Partner with The McMahon Group. Mr. Vik had served as the AAEE State Representative for Wisconsin since 1999. He had been certified in Water Supply and Wastewater Engineering since 1991. An extended profile can be found on page 8.

In Memoriam



Thomas E. Vik, P.E., BCEE

Thomas E. Vik, P.E., BCEE, a Senior Vice President and Partner with The McMahon Group, Neenah, Wisconsin, passed away on Sunday November 16, 2008. His colleagues will remember him as an innovator and a relentless achiever. He was known literally around the world as one of the very best minds in the field of wastewater engineering. Vik, 57, died from causes related to lymphatic cancer that he had been battling for a year.

A graduate of the University of Wisconsin-Milwaukee with a B.S. Degree in Environmental Engineering, Vik spent the past 28-years of his career as a Vice President and Wastewater Engineering Group Leader at McMahon, a full-service engineering and architectural consulting firm.

Vik was a Registered Professional Engineer in Wisconsin and eight other states. Throughout his career, he was active in numerous professional associations. His affiliations included the American Academy of Environmental Engineers (AAEE), Water Environment Federation (WEF), Central States Water Environment Association (CSWEA), Wisconsin Wastewater Operators Association (WWOA), Indiana Water Pollution Association, and the Wisconsin Paper Council.

Thomas E. Vik had been certified by AAEE since 1991 in Water Supply and Wastewater Engineering. Included in his service to the organization, he served as the State Representative of Wisconsin from 1999 to 2008.

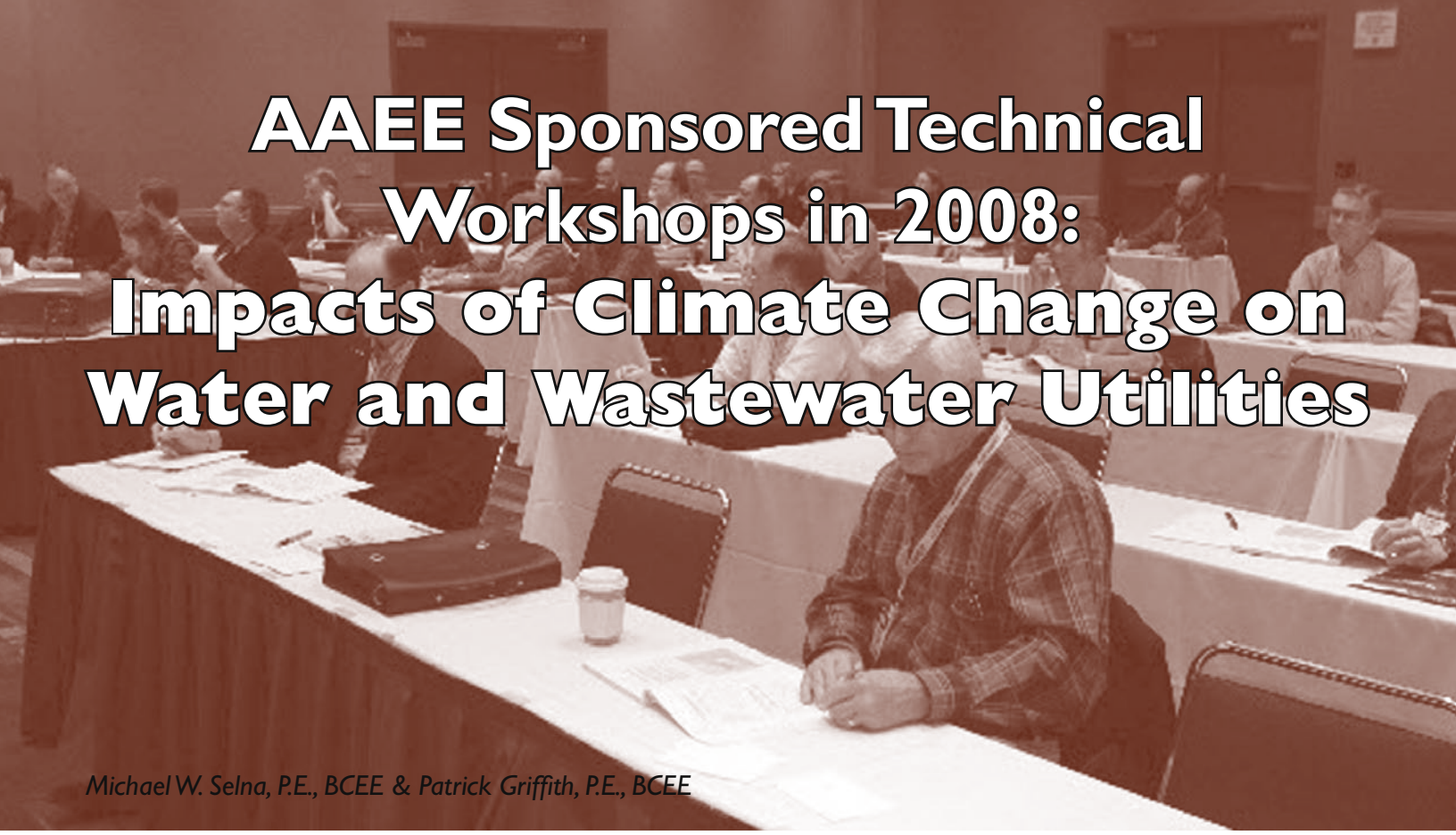
Mr. Vik served as Engineer-in-Charge of two award winning projects that McMahon Associates entered into the AAEE Excellence in Environmental Engineering Competition. Grand Chute Menasha West Wastewater Treatment Facility Upgrade was the 1996 Grand Prize winner in Design, and Sturgeon Bay Utilities Biosolds Management Facility Improvements won the 1998 Grand Prize in Small Projects.

He was also a 4-time recipient of the Central States Water Environment Association (CSWEA) Radebaugh Award for Best Technical Paper, and an Award for Energy Innovation from the U.S. Department of Energy.

Lamers called Vik a pioneer in his field, receptive to new ideas and innovative technology. "He wasn't afraid to take risks, but he was always straightforward and honest with his clients. Tom was highly respected for those reasons, as well as being a truly generous man who cared for others more than himself".

He is survived by his wife Pat of 35-years, three children and three grandchildren.

Thank you to Kari L. Dennis, P.E., Marketing Director of the McMahon Group, for granting AAEE permission to reprint this News Release.



AAEE Sponsored Technical Workshops in 2008: Impacts of Climate Change on Water and Wastewater Utilities

Michael W. Selna, P.E., BCEE & Patrick Griffith, P.E., BCEE

SUMMARY

To address growing concerns surrounding climate change and its potential impact the wastewater industry, AAEE partnered with the Water Environment Federation (WEF) to organize two workshops on this topic. Key venues were targeted to pair recognized experts with interested workshop participants to create active dialogue. The approach used in these workshops to engage the speakers and audience could serve as a model for other disciplines beginning their climate change discussions. The purpose of this brief article is to describe the structure and major outcomes of the two events held in conjunction with WEF and to direct the reader to more detailed information to be provided through AAEE and WEF.

INTRODUCTION

The Academy's five-year strategic plan outlines steps to achieve certain key goals addressing growth, visibility and its charter to advocate excellence in the profession. Aligned with these goals, the Academy Board of Trustees established an action item involving technical workshops associated with sponsoring organization conferences. Two such workshops were organized by AAEE volunteers in 2008 and conducted in conjunction with Water Environment Federation (WEF) events to highlight impact of global climate change on the water and wastewater industries.

The first AAEE/WEF workshop was held in conjunction with WEF's Sustainability 2008 specialty conference on June 22, 2008. The second was held on October 18, 2008 as a pre-conference workshop associated with WEFTEC 08. AAEE was fortunate to have excellent cooperation from WEF staff, and, in the case of the WEFTEC workshop, WEF's Air Quality and Odor Committee, chaired by Raymond Porter, was instrumental in conducting the workshop.

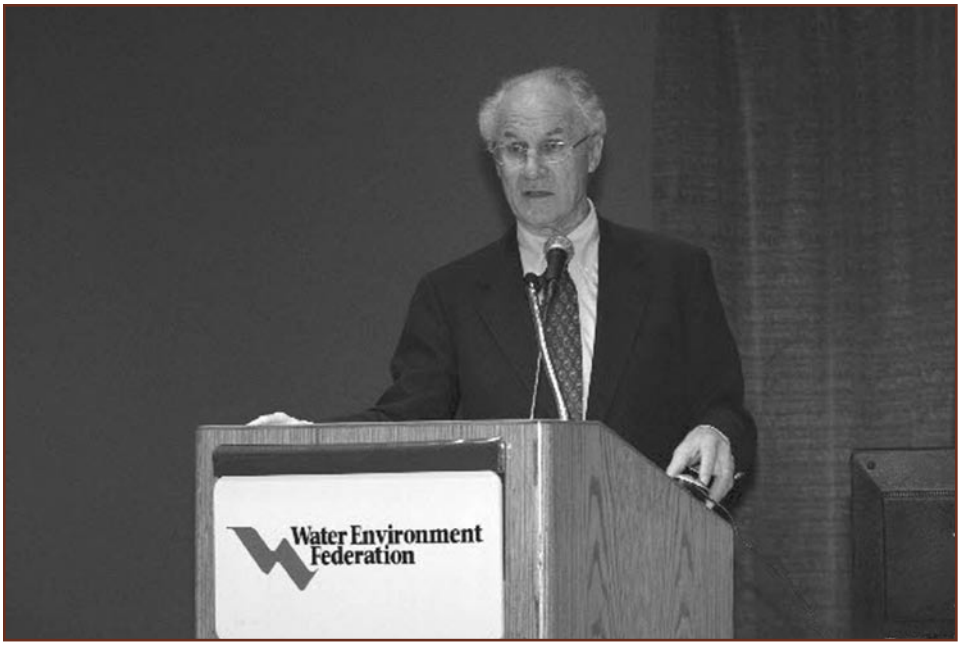
Both climate change workshops were organized to give participants background on climate change fundamentals; federal, regional, and state governmental approaches to regulation and legislation; adaptation strategies; mitigation potentials in wastewater treatment; design upgrades and associated carbon footprint; and climate change related research. Following presentations by experts on these topics, the presenters participated in a panel discussion answering questions submitted by the audience. Finally, each workshop culminated in an active breakout session, which provided an excellent opportunity for industry input on this important topic.

DISCUSSION

Climate Change Fundamentals

Human activities are very likely the cause of increased concentrations of greenhouse gases and recent acceleration in global temperatures according to the Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report. Climate models predict temperature gains of 1.1 to 6.6 degrees C by 2100 and accompanying rise of sea levels of 0.2 to 0.8 meters due to melting ice.

Climate change will result in redistribution of and increased intensity of precipitation, which will have impacts on wastewater collection and treatment facilities. Adaptation to these changes will be a challenge for wastewater utilities. Warmer water temperatures and lower stream flows will increase potential for receiving water impairment and more complex permitting. Areas with diminished rainfall will experience drinking water supply challenges, lower stream flow conditions that will make meeting effluent discharge standards more difficult, and wildfires that will result in runoff and flood impacts. Areas with increased precipitation will see more sewer overflows, more runoff and non-point pollution, and infrastructure overloading. Coastal impacts will include



wetlands displacement, saltwater intrusion to freshwater, changes in habitat/fisheries, and threats to water and wastewater infrastructure. These changes create the need for integrated water, storm water, and wastewater infrastructure planning and greater interagency coordination.

Federal Response

To address these climate change impacts, the USEPA Office of Water has developed five specific goals and 46 actions items to support the achievement of the goals. Key among mitigation strategies are improved energy efficiency and conservation at water and wastewater facilities. Adaptation strategies under review include evaluating the need for changes in drinking water, clean water, and effluent standards; creating new tools to assist watershed and wetland protection; and enhancing water infrastructure initiatives, which include sustainability guidance, clarification of the use of revolving loan funds, and the development of emergency response planning tools.

State and Regional Activity

Individual states and several regions within the US have developed initiatives aimed at reducing greenhouse gas (GHG) emissions. These programs are not specifically directed at water and wastewater utilities but impact these industries. Ten eastern states have formed the Regional Greenhouse Gas Initiative (RGGI), the nation's first greenhouse gas cap-and-trade program. RGGI deals only with power plant CO_2 emissions. The Western Climate Initiative (WCI) involves nine states and four Canadian provinces. Like RGGI and WCI, the Midwest GHG Reduction Accord, which involves six states and one Canadian province, is expected to set long-term GHG reduction targets. Among states, California and Florida were the first to establish aggressive GHG emission reduction goals. Fifteen additional states also have GHG emission reduction targets.

In addition to governmental actions, a non-governmental organization, The Climate Registry, gathers accurate, consistent GHG data into a registry for North America. The Registry will be valuable in documenting early actions to reduce GHGs and providing a cost-effective means to measure and record GHG emissions, thereby allowing entities to prepare for state and federal reporting.

Adaptation

Water and wastewater utilities can prepare for the effects of climate change by performing risk and vulnerability analyses. Key questions are: (a) What changes in climate are expected? (b) How will these changes impact the watershed environments in which wastewater utilities operate? (c) How vulnerable to these changes are the wastewater utilities? and (d) What can wastewater utilities do to manage risk? Many of the expected changes have been summarized above. Predictions of storm intensity indicate that by the year 2100 some major cities, such as Boston and Atlantic City, will experience what is presently regarded as a 100 year storm every two years, placing water and wastewater treatment facilities, normally constructed adjacent to water courses, at great risk. Profound impacts on receiving water quality are also anticipated due to increased temperature, lower flow in dry periods, and watershed impacts due to greater frequency of wildfires. Risk analysis can steer the utility toward management solutions that reduce vulnerability to these changes. Metro Vancouver has performed risk analyses providing a model of how a large wastewater utility is dealing with climate change vulnerability.

Mitigation

Wastewater treatment produces three major greenhouse gases (GHGs): carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). In comparison to CO_2, CH_4 has 21 times the global warming potential and N_2O has 310 times the potential. Overall, wastewater collection and treatment result in approximately three percent of human generated greenhouse gas emissions in the U.S. Even though this is a small portion of the total emissions, opportunities to mitigate GHGs from wastewater treatment are available in the form of improved energy efficiency, conversion of methane to energy and process controls that reduce N_2O emissions. Several of the presentations compared the GHG emissions of various wastewater treatment process configurations, including comparisons between aerobic and anaerobic processes. In general, if influent organic material can be converted to solids that are digested to produce CH_4, and if the CH_4 is efficiently captured and converted to energy, wastewater treatment can be effective in producing net GHG reductions. Efficient aeration and use of N/DN aerobic processes can result in very low net GHG production. Models are being developed to predict GHG emissions for various process configurations. There is growing concern about release of N_2O because of its GHG potential. By one estimate, the GHG potential in wastewater treatment from N_2O released in N/DN processes may be on the same order of magnitude as CO_2 emissions related to removal of COD; however, it is estimated that wastewater management produces only two percent of all N_2O releases.

Design Considerations

Adaptation, which involves designing systems to cope with the impacts of climate change, and mitigation, which involves designing systems to reduce GHG emissions, are both important sustainability concepts and are intertwined in an integrated design framework. Opportunities in integrated design include renewable energy incentives, carbon trading and increased demand for reclaimed water. Primary treatment is not expected to produce significant GHGs. Secondary treatment is anticipated to produce all three gases (CO_2, CH_4, and N_2O). Anaerobic digestion and subsequent biosolids dewatering and combustion of digester gas can be expected to produce CO_2 and CH_4. In addition, stationary and mobile sources associated with the wastewater treatment plant operation produce GHG emissions. Recycling biosolids to the land sequesters carbon in soil and plants. Avoidance of inorganic fertilizer use reduces GHG releases by reducing the use of fossil fuels in manufacture and transportation of the fertilizer, both of which dwarf the release of carbon in transport of biosolids. As an example of successful biosolids recycling to land, for all of 2007, the District of Columbia Water and Sanitation Authority Blue Plains treatment plant biosolids recycling to soil program avoided inorganic fertilizer use that would have released over 5,000 metric ton equivalents of CO_2, and approximately 25,000 metric tons of CO_2 were sequestered in the soil.

Research

The Water Environment Research Foundation has established a research program related to climate change. Eight key research projects have been developed to address climate change.

1. Wastewater focused review of climate change knowledge and research organizations.
2. White paper on climate change impacts on the wastewater industry.
3. Wastewater vulnerability handbook.
4. Case studies of historic extreme events.
5. International toolbox for navigating climate change information.
6. Wastewater industry emissions inventory and verification handbook.
7. Post discharge conversion of NH_3 and NO_3 to GHG species like N_2O.
8. Guidance on carbon trading for wastewater utilities.

Work on these projects has begun in the second half of 2008.

Breakout Session

Following the presentations and an industry panel discussion, groups of ten were formed to discuss climate change issues in the following format:

a. List the four most important adaptation/mitigation strategies for the wastewater industry
b. List major issues, gaps, or challenges related to these strategies.
c. Needs assessment: what does the industry need in the following areas to effectuate successful adaptation/mitigation
   - Legislation
   - Regulations
   - Research
   - Funding
   - Communication – within industry and with public

The output of each group has been summarized and provides valuable insight as to the state of the wastewater industry's understanding of climate change issues. The discussion revealed that the industry faces great uncertainty with respect to the impacts of climate change and little clear definition at this point on future directions. The groups understandably found it far easier to identify gaps and needs than solutions. Common themes included: closing gaps in knowledge (measuring emissions, how to mitigate and adapt), gaining public trust (key to approving/funding/permitting new projects), increased funding, defining clear goals, emphasizing integrated solutions (including breaking down regulatory "silos" and flexibility in permitting), energy efficiency improvements, flexibility in design and promoting resource recovery and reuse. A few of the greatest needs identified were providing regulatory balance (considering tradeoffs between objectives such as nutrient control, energy efficiency, and N2O release), tools for measurement and performing vulnerability analyses, and funding incentives for innovation and improvement.

Summary reports providing greater detail on the two WEF related workshops will be available through AAEE and WEF in early 2009. Access to these reports will be highlighted on the respective organization websites: www.aaee.net and www.wef.org.

ACKNOWLEDGEMENTS

The following workshop presenters are acknowledged as providing the basis for this article:

Brent Burton, Metro Vancouver;
John Cromwell, Stratus Consulting;
Patrick Hogan, Pew Center for Climate Change;
Ann McCabe, The Climate Registry;
Perry McCarty, Stanford University;
Chris Peot, DC WASA;
Bob Raucher, Stratus Consulting;
Glenn Reinhardt, WERF;
Diego Rosso, UC Irvine;
Michael Shapiro, U.S. EPA;
Michael Stenstrom, UCLA;
Nancy Stoner, NRDC;
Claudio Ternieden, WERF; and
Jay Witherspoon, CH2M HILL. A

THE 2009 KAPPE LECTURER

RAO Y. SURAMPALLI, PH.D., P.E., BCEE, F.AAAS

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Engineer Director
United States Environmental Protection Agency

DR. RAO Y. SURAMPALLI, Engineer Director with United States Environmental Protection Agency (USEPA), has been with EPA for the past 23 years. His career in private practice, government, university and applied research has given him the opportunity to experience and appreciate the varied interests and challenges of the environmental engineering profession. His main expertise is in the area of water/wastewater treatment, sludge treatment/disposal, hazardous/solid waste management, and soil and groundwater treatment.

He has authored more than 400 technical publications, including 8 books, 42 book chapters, 142 refereed (peer-reviewed) journal articles, presented at more than 190 national and international conferences, edited 12 refereed conference proceedings, and given over 60 plenary, keynote or invited presentations worldwide. Currently, he serves on many national and international committees, review panels, or advisory boards including the ASCE's National Committee on Energy, Environment and Water Policy. He is Editor of two well known refereed journals – the *Water Environment Research Journal* published by the Water Environment Federation (WEF), and the *Hazardous, Toxic, and Radioactive Waste Management Journal* published by the American Society of Civil Engineers (ASCE). He also serves on the Editorial Boards of three other refereed Environmental Journals. He is as well an Adjunct Professor of Environmental Engineering at six universities: Iowa State University-Ames, University of Missouri-Columbia, University of Nebraska-Lincoln, University of Quebec-Sainte Foy, Tongji University-Shanghai, and Missouri University of Science and Technology-Rolla. He also is an Honorary Professor in Sichuan University-Chengdu.

He has provided technical assistance, facilitated technology transfer, and built technical capacity for numerous developed and developing nations including Brazil, India, Nepal, Taiwan, Japan, Thailand, Philippines, Namibia, Kazakhstan, Panama, Germany, Slovenia, Hong Kong, Ghana, China and Korea. A noteworthy humanitarian, his most recent voluntary contributions include working in India, Namibia, Kazakhstan and Panama to develop environmental protection and improvement programs. He was also selected to participate on a multi-disciplinary engineering team organized by the ASCE to evaluate the ecological and environmental impacts of the 2004 Indian Ocean Tsunami.

Named a Distinguished Engineering Alumnus of both the Oklahoma State University and Iowa State University, Dr. Surampalli was elected a Fellow of the American Association for the Advancement of Science (AAAS) in 2005, and a Member of the European Academy of Sciences and Arts (EASA) in 2008. AAAS is the world's largest scientific society and election as a fellow recognizes an individual for his/her "efforts toward advancing science or fostering applications that are deemed scientifically or socially distinguished". He also is a Fellow of the American Society of Civil Engineers.

EDUCATION

Oklahoma State University, MS
Iowa State University, Ph.D.

PROFESSIONAL CREDENTIALS

Registered Professional Engineer
Board Certified Environmental Engineer, American Academy of Environmental Engineers
Diplomate, American Academy of Water Resources Engineers
Fellow, American Association for the Advancement of Science
Fellow, American Society of Civil Engineers
Member, European Academy of Sciences and Arts

PROFESSIONAL HONORS

National Government Civil Engineer of the Year
State-of-the-Art of Civil Engineering Award
Rudolph Hering Medal
Wesley Horner Medal
Best Practice Oriented Paper Award
Founders Gold Medal
National Federal Engineer of the Year
Top Ten Federal Engineers of the Year
Philip Morgan Award
Scientific and Technological Achievement Award
EPA Engineer of the Year
Outstanding Service Medal
Hollis Medal
Distinguished Military Service Award
Samuel Lin Award

Abstracts of Lectures Offered

Nanotechnology and the Environment

Nanotechnology presents new opportunities to create better materials and products. Applications of nano-materials in environmental protection have created conditions to improve environment and control pollution, which will bring breakthrough progress to environmental science and engineering. Using nano-materials to solve environmental issues will become an inexorable trend in the future. Applications of nano-materials in green chemistry, photocatalytic degradation of organic pollutants, remediation of polluted soils or water, pollutant sensing and detection, and so on, have been introduced. Our economy will be increasingly affected by nanotechnology as more products containing nanomaterials move from research and development into production and commerce. Nanotechnology also has the potential to improve the environment, both through direct applications of nanomaterials to detect, prevent, and remove pollutants, as well as indirectly by using nanotechnology to design cleaner industrial processes and create environmental friendly products. However, there is a need for research to better understand and apply information regarding nanomaterials such as: chemical identification and characterization, environmental fate, environmental detection and analysis, potential releases and human exposures, human health effects assessment, ecological effects assessment, and environmental technology applications. The presentation will discuss the potential environmental applications of nanomaterials and nanotechnologies.

Emerging Contaminants of Environmental Concern

Emerging contaminants of environmental concern have been wildly distributed in the environment and attracted increasing attention over the past decades. The emerging contaminants include endocrine-disrupting compounds, surfactants and their degradation products, plasticizers, pesticides, retardants, and nanoparticles. These compounds can enter the environment after their application, after use they are usually discharged into municipal sewer systems and afterwards treated in wastewater treatment plants, where they are completely or partially removed by a combination of sorption and biodegradation. Many studies have confirmed the presence of complex mixtures of unregulated contaminants, having various origins, and raised concern about their potential interactive effects. These substances among different phases (air, water and sediment/soil) in the environment are presented. Their occurrence and behavior (fate and transport) in natural and engineered systems including treatment are discussed.

The Kappe Lecture Series was inaugurated by the Academy in 1989 to share the knowledge of today's practitioners with tomorrow's environmental engineers. It is an annually recurring series of lectures presented on college campuses during the Fall academic term.

This program was inspired by a grant from the estate of Stanley E. Kappe, P.E., BCEE, who passed away in 1986. Mr. Kappe served as the Academy's Executive Director from 1971 to 1981. He was a successful environmental engineer who believed he owed a debt to the profession that had rewarded him so well. During his life, he gave of himself to his university (Pennsylvania State University) and to his profession through countless hours of volunteer activity. Through this lecture series, he continues to share his good fortune with tomorrow's environmental engineers.

All colleges and universities with an environmental engineering program are eligible to participate. If you are interested in having a Kappe Lecturer visit your school, please contact Academy Headquarters.

2010 Officer Nominees

Full profiles and voting ballots will be available in the Spring issue of *Environmental Engineer*®.

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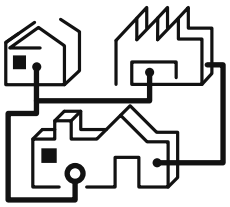
Academy News

continued from page 14

ENVIRONMENTAL ENGINEER: APPLIED RESEARCH AND PRACTICE

Included in this issue of *Environmental Engineer* is the newest volume of *Environmental Engineer: Applied and Research* (page 27). This edition includes **Mitigation of Ozone-Induced Bromate by Carbon Dioxide and Chlorine/Ammonia Processes** by David Eberle, Zaid Chowdhury, Laurel Passantino, and Steve Bontrager.

Journal Editor, Dr. C. Robert Baillod, P.E., BCEE, along with the Editorial Board, invites authors to submit their papers. Particularly of interest are papers focused on practical research and use case studies related to environmental engineering.



Stay Connected!

AAEE likes to keep its membership updated on news, events, reminders, and other pertinent information. If you haven't been receiving any emails from us but would like to, simply update your membership information with AAEE Headquarters. Email the Academy at info@aaee.net.

AAEE does *not* sell or distribute emails to third parties.

The Class of 2008

THESE INDIVIDUALS were Board Certified in November 2008.

From the first applicants in 1956 to the 110 Board Certified Environmental Engineers and Board Certified Environmental Engineering Members listed on the following pages, the Academy has undergone growth and changes, but has never wavered from it's core objective to "identify and credential persons with special capabilities in environmental engineering."

Today, there are nearly 2,500 Board Certified Environmental Engineers and Board Certified Environmental Engineering Members in the Academy and interest continues to grow on an annual basis.

A brief description of the specialty certification process follows: To be included in an annual class, the application for specialty certification must be submitted to the Academy by March 31. Any application received after that date is held over to the next class. The applications received by March 31 are then reviewed by the Admissions Committee for adequacy of education and qualifying experience in April and May. Examinations are administered to the qualified applicants during July and August at convenient locations throughout the country. The examination results are reviewed by the Admissions Committee in September and recommendations for each candidate are presented to the Board of Trustees. Each person's history is reviewed by the Board members at the Academy's Annual Meeting and decisions made to certify or not.

THE ACADEMY announces the issuance of specialty certificates and Board Certified Environmental Engineers and Board Certified Environmental Engineering Members status to those individuals portrayed in this special section of the Environmental Engineer®. These persons have demonstrated to their peers that they possess the requisite formal education and environmental engineering practical experience and have successfully completed the Academy's examinations to be Board-Certified environmental engineering specialists. The special capability of each person is shown after their name using the following codes:

AP	Air Pollution Control,	HW	Hazardous Waste Management,	SW	Solid Waste Management,
GE	General Environmental Engineering,	IH	Industrial Hygiene,	WW	Water Supply and Wastewater Engineering.
		RP	Radiation Protection,		

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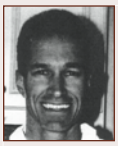

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The American Academy of Environmental Engineers returned as an exhibor at the WEFTEC trade show, held as part of the Water Environment Federation's 81st Annual Exhibition & Technical Conference. The 2008 event was held in Chicago, Illinois on October 19 through October 22.

A number of Academy members volunteered to staff the booth, which drew a steady flow of traffic. In addition to current members, many prospective Academy members stopped to visit.

Catherine Graef, AAEE Executive Director Joseph S. Cavarretta, CAE, Stephen F. Graef, Ph.D., P.E., BCEE, and Michael W. Selna, P.E., BCEE

Three AAEE Past Presidents: Charles A. Willis, P.E., BCEE (1997), Robert C. Marini, P.E., BCEE (1995), and Jeanette A. Brown, P.E., BCEE (2004)

AAEE Executive Director Joseph S. Cavarretta, CAE, and Immediate Past President William P. Dee, P.E., BCEE.

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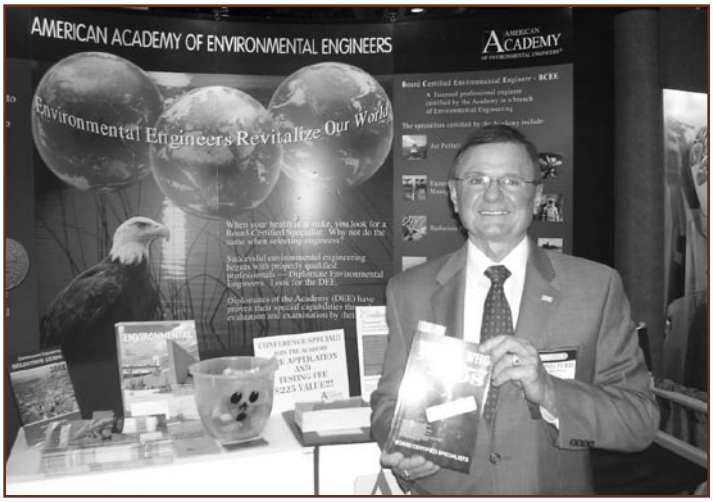
Joseph S. Cavarretta, CAE, and Stephen F. Graef, Ph.D., P.E., BCEE, assemble the AAEE Booth.

The completed AAEE Booth.

Richard F. Lanyon, P.E, BCEE, and Glen T. Daigger, Ph.D, P.E., BCEE.



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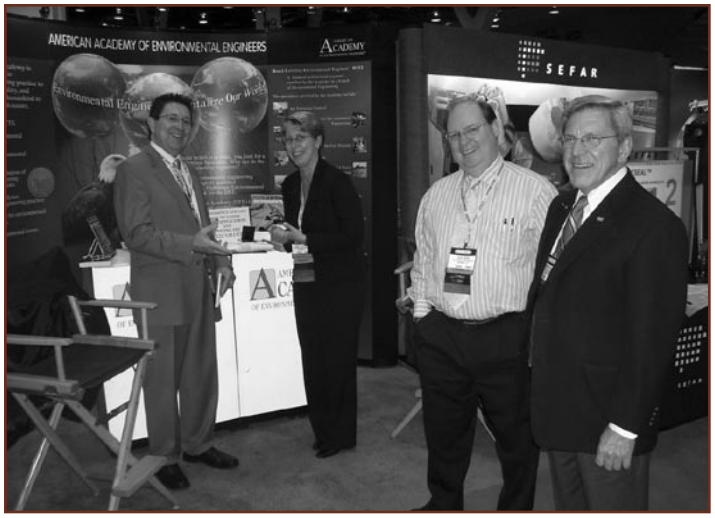

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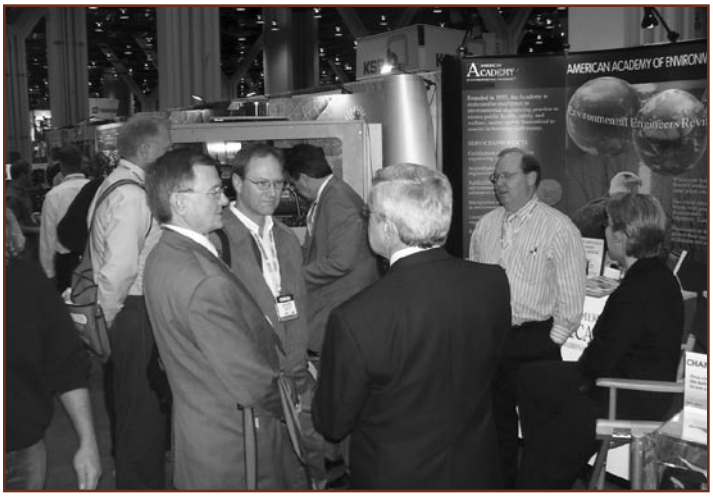

The AAEE Booth enjoyed a steady flow of traffic from both current and new prospective members.

AAEE would like to give a special *'Thank You'* to Steve Graef for supplying the photos for this feature.

Volume 7, Winter 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.

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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:

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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.

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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.

PHOTOGRAPHIC CONSENTS

A letter of consent must accompany all photographs of persons in which the possibility of identification exists. It is not sufficient to cover the eyes to mask identity.

License to publish will be required.

MITIGATION OF OZONE-INDUCED BROMATE BY CARBON DIOXIDE AND CHLORINE/AMMONIA PROCESSES

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ABSTRACT

Mitigation of ozone-induced bromate by carbon dioxide and chlorine/ammonia processes was studied at the Greenway Water Treatment Plant located in Peoria, AZ. Plant scale and bench-scale testing were performed to assess practicality and to determine the influence of source water on bromate formation, especially with respect to bromide concentrations. Results indicated that both of the approaches were able to reduce bromate yield by 35 percent or more depending on the raw water quality. Mitigation effectiveness depended on the ozone/TOC dosage, and at an O_3/TOC ratio of 1.0 mg/mg, neither process was expected to reduce bromate formation below 8 µg/L on a consistent basis. Carbon dioxide addition appeared to perform slightly more consistently compared to the chlorine/ammonia process. However, based on other economic, social, and environmental considerations not discussed in this paper, the chlorine/ammonia process appeared to be the best alternative to mitigate bromate formation in order to allow higher ozone dosages and thereby enhance taste, odor, and TOC removal.

INTRODUCTION

Since the first ozone water treatment plant was constructed in 1893, municipal water utilities around the world have been utilizing the disinfection properties of ozone (Langlais et al. 1991). One hundred years later, the interest in ozone continued as the suspected carcinogenic properties of trihalomethanes, formed when natural organic matter reacts with chlorine, became more publicized. With over 250 water treatment plants utilizing ozone in the United States alone, the number of utilities considering the use of ozone for water treatment remains on the rise (Hesby 2005).

Ozone (O_3) is an unstable and highly reactive molecule with strong oxidizing capabilities. In water treatment, O_3 is primarily used for oxidation (e.g. taste and odor, color, and micropollutants) and disinfection (viruses, *Giardia lamblia*, and *Cryptosporidium*). Because of the molecule's reactivity, however, the formation of disinfection byproducts (DBPs) may also result; specifically bromate (BrO_3^-). In 1998, the United States Environmental Protection Agency (USEPA) promulgated the Stage 1 Disinfectants/ Disinfection By-Products Rule, which established a maximum contaminant level (MCL) of 10 µg/L for bromate (BrO_3^-), based on a running annual average of monthly samples (USEPA, 1998). At the time of setting this standard, it was accepted that a health based standard would be lower, but the practical analytical limit at that time did not allow setting a lower standard. Therefore, it is possible that the standard will be lowered in the future. With BrO_3^- formation a function of water quality characteristics including bromide (Br^-) concentration, temperature, ozone dose, natural organic matter, pH, and contact time, some utilities have resorted to BrO_3^- mitigation strategies in order to maintain a consistent CT without violating the MCL (Amy et al. 1998a).

BrO_3^- is formed through complex, multi-step interactions of bromide (Br^-) with molecular O_3 and hydroxyl radicals (OH•) that are formed during ozonation of water. To reduce BrO_3^- formation during ozonation, utilities commonly lower pH, add hydrogen peroxide (H_2O_2), or add ammonia (NH_3) prior to ozonation. Among them, lowering pH is perhaps the most well-known and widely practiced way by which BrO_3^- mitigation has been carried out in the past. To reduce BrO_3^-, the water's pH is reduced through mineral acid (e.g. sulfuric acid) or carbon dioxide (CO_2) addition. Lowering the pH decreases the OH• concentration, decreasing BrO_3^- formation via the OH• pathway. A less conventional method of adding H_2O_2 after O_3 addition acts to quench molecular O_3. If BrO_3^- is primarily formed via the molecular O_3 pathway, reducing O_3 concentrations will help to mitigate BrO_3^- formation. Other studies have shown the addition of NH_3 also reduces BrO_3^- formation through the creation of bromoamines, which are subsequently converted to Br^- and nitrate during reactions with O_3 (Amy et al. 1998a). Further investigations of the NH_3 process have shown that the addition of a small amount of chlorine (Cl_2) prior to NH_3 addition will reduce BrO_3^- formation beyond that of NH_3 addition alone (Wert et al. 2007). The addition of Cl_2 prior to NH_3 helps to oxidize Br^- to hypobromous acid before it reacts with NH_3 to form bromoamines (Buffle, 2004).

The City of Peoria, Arizona (City) Greenway Water Treatment Plant (GWTP) uses pre-ozonation followed by conventional flocculation/sedimentation, biologically active GAC filtration, and chlorination (Figure 1). The GWTP lies at the end of the Arizona Canal (Figure 2); its source water, controlled by the Salt River Project (SRP), consists of groundwater pumped

FIGURE 1 City of Peoria Greenway WTP Process Flow Diagram

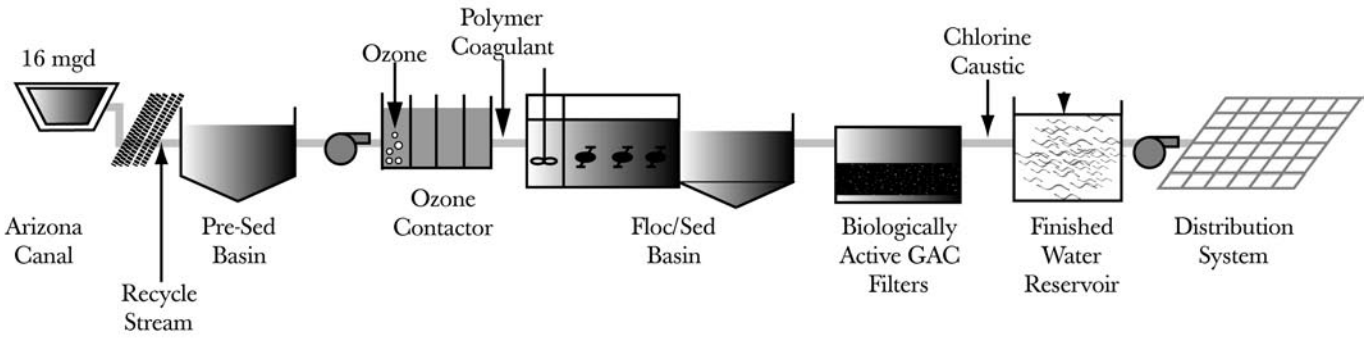
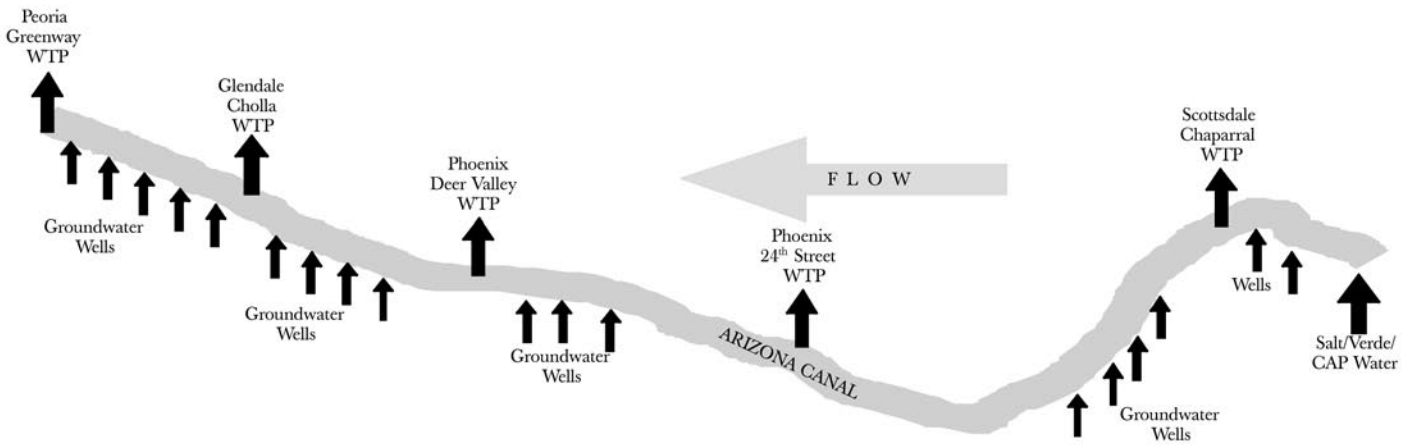


FIGURE 2 Greenway WTP Source Water Contributions



from wells along the canal and surface water from the Salt and Verde Rivers and the Central Arizona Project (CAP) Canal. With other water treatment plants and agricultural customers also receiving water from the canal, GWTP's source water quality changes daily. Presently, O_3 at the GWTP is not used at sufficient doses to achieve primary disinfection; however, the applied dose is believed to be aiding the removal of taste and odor (T&O) compounds and enhancing biofiltration. Due to the presence of moderate and fluctuating concentrations of Br^- in the source water, O_3 dosages are kept to a minimum to control the formation of BrO_3^- below the City's target of less than 8 micrograms per liter (µg/L), which is 80 percent of the MCL.

In 2005, an initial study of the GWTP ozonation and GAC filtration processes was conducted to further optimize its operation by lowering BrO_3^- formation and improving the removal of disinfection byproduct (DBP) precursors and T&O compounds. The primary reasons for this study were:

- An optimized ozonation step will ensure reliable compliance with the BrO_3^- MCL while increasing the disinfection ability for the unit process.
- Improving the removal of total organic carbon (TOC) through optimized operation of the ozone system and GAC biological filters will reduce DBP concentrations in the distribution system, in particular, total trihalomethanes (TTHM), aiding in compliance with the Stage 2 DBP Rule which will commence in 2012.
- The optimized use of ozonation and GAC biological filtration will result in better tasting water due to additional removal of T&O compounds.

The initial study utilized bench-scale testing to evaluate three potential BrO_3^- mitigation strategies: pH depression, Cl_2/NH_3 addition, and H_2O_2 addition. Two of the mitigation strategies tested on the bench-scale, pH depression and Cl_2/NH_3 addition, were determined to be effective in controlling BrO_3^- to a very low level while allowing more effective utilization of the ozonation system. The study recommended that full-scale demonstration testing of these two alternatives be performed before one of the approaches was selected for full-scale implementation. The study also recommended that the impacts of GWTP's source water on Br^- concentrations and BrO_3^- formation be evaluated. The objectives of the follow-up full-scale demonstration testing and supplemental bench-scale testing follow-up study, described herein, were to:

- Compare the effectiveness of CO_2 addition and the Cl_2/NH_3 processes in mitigating BrO_3^- formation at plant scale, allow operators the opportunity to gain familiarity with the processes, and identify any system constraints that should be considered during the design phase.
- Determine the impact of water quality variations in the Arizona Canal on BrO_3^- formation, especially with respect to Br^- concentrations through bench-scale experiments.

FIGURE 3 CO_2 Addition Testing Schematic

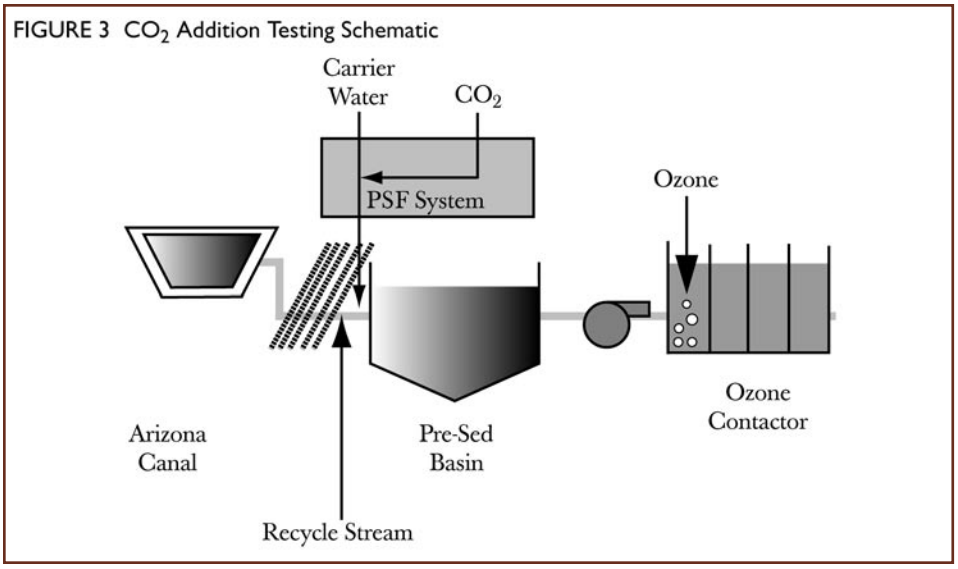
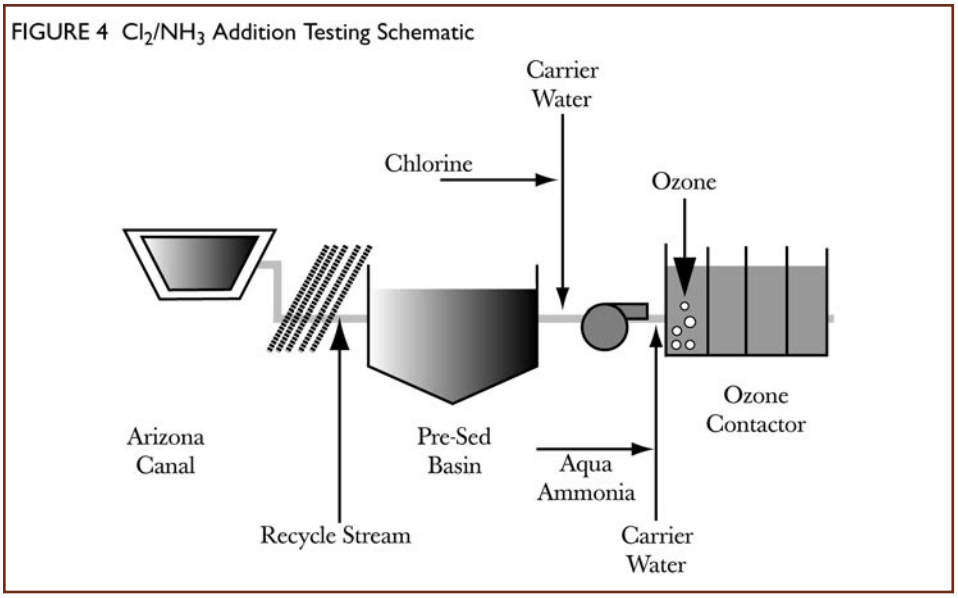


FIGURE 4 Cl_2/NH_3 Addition Testing Schematic



METHODS AND MATERIALS

Full-Scale Testing Overview

Full-scale demonstration testing of the two BrO_3^- mitigation strategies was conducted from February to September 2008. Carbon dioxide addition testing was performed from February 27, 2008 to April 2, 2008, when plant flows averaged 7.1 mgd. Because of various water quality and O_3 system limitations, the period between March and July was spent preparing for the Cl_2/NH_3 process testing. Cl_2/NH_3 testing was performed from July 15, 2008 to September 2, 2008, when plants flows averaged 11.5 mgd. During the full-scale demonstration, the raw water pH ranged from 7.0 to 8.3, and the raw water temperature ranged from 14°C to 34°C.

Carbon Dioxide Addition. CO_2 was injected prior to the pre-sedimentation basin (5.8 hour detention time at 7.1 mgd). The CO_2 addition system consisted of a pressure-controlled CO_2 storage tank piped to a pressurized solution feed (PSF) system (Figure 3). Within the PSF system, CO_2 was mixed with a carrier water under pressure (at or above 55 psi) through a series of baffles. The carrier water was then injected into the plant's raw water via a stainless steel diffuser. By injecting the CO_2 into the carrier water under pressure, greater CO_2 dissolution can be achieved, reducing the volume of CO_2 that off-gases into the atmosphere. During operation, the flow of the carrier water remained constant, but the amount of CO_2 injected into the carrier water varied as a function of the raw water pH and the desired pH set point. A pH probe located 30 to 90 seconds downstream of the CO_2 solution feed point relayed information back to the PSF panel, which opened or closed a pneumatically-controlled value to adjust the CO_2 feed rate and pH.

The pressure and phase of the CO_2 in the storage tank was controlled by a heating and cooling system. When the pressure in the tank dropped below 350 psi (e.g., during high CO_2 feed rates), a heater warmed the liquid CO_2 and prevented the formation of ice. Similarly, when the pressure increased because of warm ambient air conditions or infrequent use, a refrigeration unit cooled the solution and prevented unnecessary CO_2 off-gassing into the atmosphere.

The PSF system was temporarily installed prior to the rapid mix chamber located at the head of the plant. A pH probe downstream of the injection point continually monitored the pH and adjusted the CO_2 dose accordingly to achieve the desired pH set point. To aid in the mixing of the carrier and plant waters, the rapid mixer remained on during testing. The plant was started up and allowed to reach equilibrium (baseline conditions). Starting at a pH of 7.2, the O_3/TOC ratio was gradually increased from 0.5 mg/mg to 1.0 mg/mg while maintaining BrO_3^- at or below 8 µg/L at the O_3 contactor effluent. Due to the time needed to analyze BrO_3^- samples in the laboratory, the O_3/TOC ratio was not increased by more than 0.2 mg/mg until BrO_3^- samples were analyzed and recorded in the laboratory.

During the second phase of pH depression testing, an O_3/TOC ratio of 1.0 mg/mg was continually applied to the water to assess any increases in biofiltration that may have resulted from higher O_3/TOC ratios. During this period, the pH was also varied between 6.5 and 7.2 to gather more data on the effect of lowering pH and the CO_2 doses needed to reach the desired pH. During the last five days of testing, the pH was adjusted to 7.2 and the O_3/TOC ratio was lowered back to 0.5 mg/mg to gather more data on the effect O_3/TOC ratio had on BrO_3^- formation. Following the completion of the CO_2 addition testing, GWTP was returned to baseline conditions by lowering the O_3/TOC ratio to 0.5 mg/mg and removing the CO_2 addition equipment.

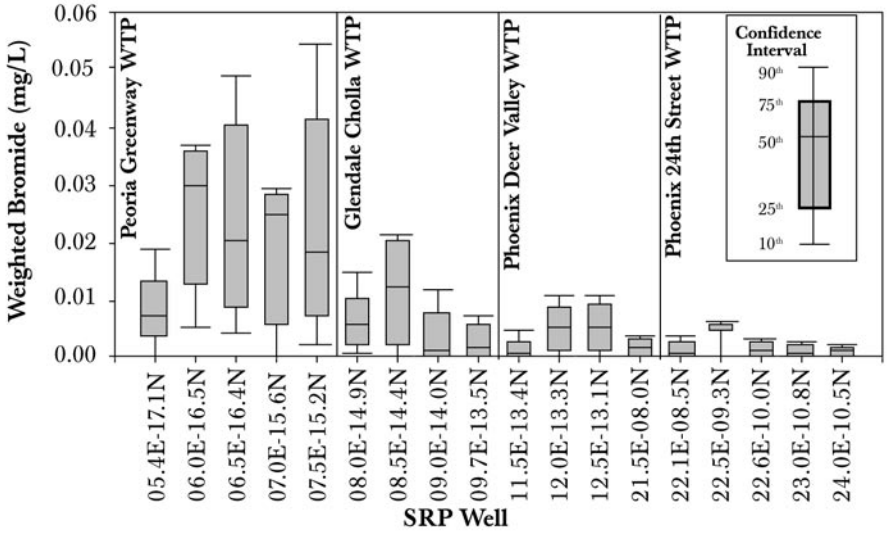
Bromate was measured at two locations: O_3 contactor effluent and finished wa-

ter reservoir. Because of the long detention time in the plant, finished water BrO_3^- concentrations were used only to confirm compliance with the BrO_3^- MCL. The study focused more on BrO_3^- formed at the O_3 contactor effluent and did not address the fate of BrO_3^- within the plant. O_3/TOC ratio, pH, CO_2 dose, and caustic dose were manually recorded by operators at 4-hour intervals. Raw, settled, and finished water TOC were sampled two times per day at each location by an online TOC analyzer. TOC data and other plant data (plant flows, etc.) were obtained from GWTP's supervisory control and data acquisition (SCADA) system.

Chlorine/Ammonia Addition. Cl_2/NH_3 testing was carried out by temporarily relocating a Cl_2 solution feed line to the pre-sed basin effluent (6 minute detention time before NH_3 addition at 11.5 mgd) and installing a temporary NH_3 chemical feed system immediately prior to the O_3 contactor (2 minute detention time before O_3 addition at 11.5 mgd), shown schematically on Figure 4. Cl_2 gas (pulled under vacuum) was diffused into a carrier water and carried to the pre-sedimentation effluent channel where it was diffused into the plant's raw water. A 19 percent solution of aqua ammonia, also carried by a separate carrier water to aid in chemical dissolution, was added to the plant water immediately prior to ozonation. Following ozonation, coagulation/sedimentation, and filtration, additional Cl_2 was added in sufficient doses to remove excess NH_3 and provide a free Cl_2 residual throughout the distribution system, complying with all federal and state water quality regulations.

Following the construction of the temporary Cl_2 and NH_3 feed systems, startup and optimization of the system commenced on July 15, 2008. Starting with a Cl_2 dose of 4.0 mg/L and NH_3 dose of 0.3 mg/L, the O_3/TOC ratio was gradually increased from 0.5 mg/mg to 1.0 mg/mg. With elevated concentrations of BrO_3^- detected at the O_3 contactor, the O_3/TOC ratio was decreased to 0.8 mg/mg, and the Cl_2 dose was optimized by varying the Cl_2 dose between 4.0 and 1.0 mg/L and collecting BrO_3^- samples every hour. Similarly, the NH_3 dose was also adjusted between 0.1 and 0.6 mg/L to achieve the lowest BrO_3^- yield while keeping a constant Cl_2 dose.

FIGURE 5 Weighted Bromide in the Arizona Canal



Throughout the course of testing, the O_3/TOC ratio was adjusted to keep BrO_3^- formation below the 8 µg/L target. The Cl_2 dose and NH_3 dose were continually varied to verify optimized doses had been achieved. On multiple occasions, samples were collected in a single day when raw water quality was constant. During the last three weeks of testing, GWTP operators applied an O_3/TOC ratio of 0.8 mg/mg to determine if an increased O_3/TOC ratio improved biofiltration. Following the completion of the Cl_2/NH_3 addition testing, GWTP operators returned the plant to baseline conditions by lowering the O_3/TOC ratio to 0.5 mg/mg and removing the Cl_2/NH_3 addition equipment.

Similar to CO_2 addition testing, Br^- and BrO_3^- samples were collected and analyzed by the City daily in order to calculate BrO_3^- yield. O_3/TOC ratio, Cl_2 dose, and NH_3 dose were manually recorded by operators at 4-hour intervals. Raw, settled, and finished water TOC were sampled twice a day using an online TOC analyzer. TOC data and other plant data (plant flows, etc.) were obtained from GWTP's SCADA system.

Bench-Scale Testing Overview

The bench-scale water quality testing performed as part of this study consisted of two phases: raw water collection/blending and bench-scale testing. After collecting and analyzing SRP surface waters and water from two production wells, six simulated raw waters were produced, representative of GWTP's historical raw water quality and potential raw water quality during extended drought conditions (limited surface water). After the simulated waters were blended, bench-scale ozonation tests were performed to determine the impact of water quality on BrO_3^- formation.

Raw Water Collection/Blending. The potential Br^- impact each well could have on GWTP's raw water was determined by considering well Br^- concentrations, well flow rates, well operation frequencies, the proximity of the well to GWTP, and other WTP demands. Two wells (6.5E 16.4N and 12.5E 13.1N) were identified that could potentially have the greatest impact on GWTP's raw water quality (Figure 5). Although other wells had a higher potential to contribute Br^- to GWTP's raw water, Well 12.5E 13.1N was selected because of its high Br^- level and alkalinity.

Five gallons of Salt River water and Verde River water were collected from Blue Point Bridge and along the Beeline Highway just west of Fort McDowell Road, respectively. Five gallons of water from each wellhead were also collected following a 15-minute well purge. All waters were stored at 4°C until the optimized BrO_3^- mitigation strategy doses were determined in the full-scale demonstration testing. Raw water samples were sent to the City for Br^- analysis; TOC was measured at Arizona State University. The results of the analyses were used to blend the waters to represent the simulated raw water conditions shown

TABLE 1 Simulated Raw Water Scenarios for Bench-Scale Testing

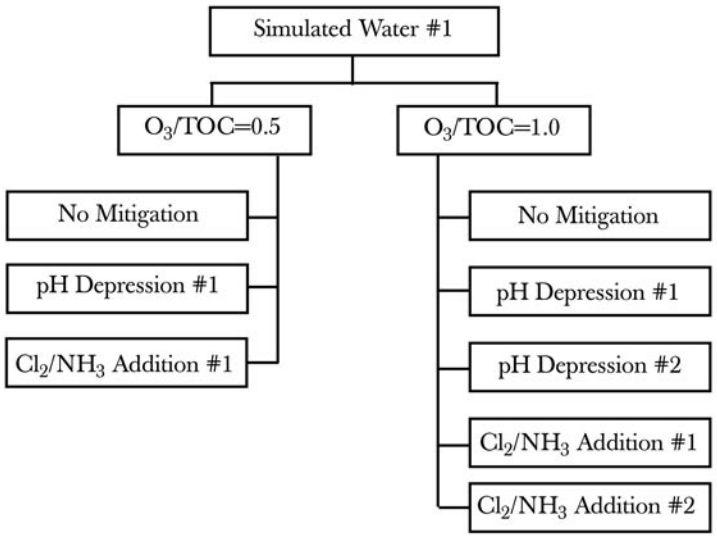
	Simulated Raw Water Scenario	Water Source	TOC (mg/L)	Bromide (µg/L)
1	Extreme Drought Conditions	Wellhead 12.5E 13.1N	1.2	872
2	Reasonable Drought Conditions	Wellhead 6.5E 16.4N	1.5	443
3	Typical Summer Water with Average Winter Rain	Salt River	4.7	120
4	Typical Winter Water with Average Winter Rain	Verde River	3.9	45
5	Summer Water with Elevated Br^-	Salt River and Wellhead 6.5E 16.4N Blend	3.8	516
6	Winter Water with Elevated Br^-	Verde River and Wellhead 6.5E 16.4N Blend	3.0	443

TABLE 2 Bench-Scale Testing Conditions

Strategy	pH	CL_2 Dose (mg/L)	CL_2 Contact Time (min)[1]	NH_3 Dose (mg/L)	NH_3 Contact Time (min)[2]
pH Depression #1	6.8	-	-	-	-
pH Depression #2	6.5	-	-	-	-
CL_2/NH_3 Addition #1	Ambient	1.0	5	0.3	1
CL_2/NH_3 Addition #2	Ambient	0.5	5	0.3	1

Notes:
1 Prior to ammonia addition
2 Prior to ozone addition

FIGURE 6 Bench-Scale Testing Algorithm



in Table 1. After blending the waters, the City analyzed Br^-, alkalinity, and pH of the simulated waters.

Bench-Scale Testing. Following completion of the raw water blending and analyses, bench-scale batch ozonation tests were performed. For each of the simulated waters described above, an O_3/TOC ratio of 0.5 and 1.0 mg/mg was applied using a liquid O_3 solution for each of the three mitigation strategies (no mitigation, pH depression, and Cl_2/NH_3 addition). Lowering the pH with CO_2 is a difficult process in the laboratory. For this reason, sulfuric acid (H_2SO_4) was used instead. For Cl_2/NH_3 addition, sodium hypochlorite and aqua ammonia were used. Each test was carried out in 40-mL vials at room temperature (23°C). Similar to the full-scale operation, no O_3 quenching agents were used. The testing algorithm for one of the six simulated waters is depicted on Figure 6. Chemical dosing and detention times for the BrO_3^- mitigation strategies were determined from the results of the full-scale demonstration optimization periods (Table 2). The City analyzed samples for BrO_3^-; MWH Laboratories analyzed samples for TTHMs. Water quality results were adjusted to account for the dilution caused by the liquid ozone solution.

Analytical Methods

Br^- (EPA 300.0) and BrO_3^- (EPA 300.1) were measured using the City's ion chromatograph (ICS-2000). TOC was either measured using the City's online TOC analyzer (ultraviolet/ persulfate oxidation) or the local university TOC analyzer, both which complied with USEPA-approved Standard Method 5310C and proposed EPA 415.3. Alkalinity (titrated with 0.02N H_2SO_4 and methyl purple) and pH (Fisher Scientific Accumet AR60 dual channel meter with an Accumet gel probe) were measured by water treatment technicians in the GWTP laboratory. TTHM samples (EPA 551.1) were sent to MWH Laboratories for analysis.

RESULTS AND DISCUSSION

Full-Scale Testing

Bromate Yield. Bromide and BrO_3^- samples were collected and analyzed by the City on a daily basis. In a 1998 study, Amy et al. determined that relationship between BrO_3^- formation and raw water Br^- was almost linear when other water quality parameters remained constant (1998b). In order to adjust for variable Br^- concentrations in the raw water and compare both BrO_3^- mitigation strategies, BrO_3^- was reported as BrO_3^- yield (BrO_3^-/Br^-).

During CO_2 addition testing, Br^- concentrations ranged from 36 to 95 µg/L and averaged 49 µg/L. Br^- in Verde River water, the primary source water during testing, have historically been 40-50 µg/L. Br^- peaks noted at the end of the testing were likely the result of Salt River water in the source water mix. Because the Br^- concentration, ozonated pH, and O_3/TOC ratio varied during testing, O_3 contactor BrO_3^- ranged from <2 µg/L to 12.2 µg/L. Reservoir effluent BrO_3^- ranged from <2 µg/L to 7.7 µg/L. BrO_3^- yield as a function of O_3/TOC ratio at pH 7.2 is shown on Figure 7 (along with confidence intervals when sufficient data were collected). As expected, BrO_3^- yield increased as the O_3/TOC ratio increased. At an O_3/TOC ratio of 1.0 mg/

mg, reducing the pH from 8.0 to 7.2 reduced the 50th percentile BrO_3^- yield from 0.18 µg/µg to 0.15 µg/µg. Applying the relationship indicated in Figure 7, at pH 7.2 and average GWTP raw water Br^- (100 µg/L), an O_3/TOC ratio of approximately 0.6-0.7 mg/mg estimates BrO_3^- formation below the 8 µg/L target. At the same pH and Br^- concentration, applying an O_3/TOC ratio of 1.0 mg/mg would likely have produced 15 µg/L BrO_3^-, which is higher than the City's target and the federal MCL. In this case, the pH would need to be lowered in order to reduce BrO_3^- formation and allow the City to apply a higher O_3/TOC ratio.

BrO_3^- yield as a function of pH at an O_3/TOC ratio between 0.95 and 1.0 mg/mg is shown on Figure 8. Because only a few tests were performed at pH 6.6, 6.8, and 7.0, individual data points are shown. Confidence intervals are only shown for pH 7.2. In this case, BrO_3^- formation generally decreased as the pH was lowered from 7.2 to 6.6. In order to meet the 8 µg/L target when applying an O_3/TOC ratio of 1.0 mg/mg to average Br^- water (100 µg/L), the pH would need to be lowered to approximately 7.0.

During Cl_2/NH_3 demonstration testing, Br^- ranged from 81 to 153 µg/L and averaged 104 µg/L. This level was almost twice the level observed during the CO_2 testing. Much of the raw water was originating from the Salt River where Br^- (100-150 µg/L) are more than double that of the Verde River. The Br^- peaks noted during the testing were likely the result of higher Salt River water and groundwater contributions in the source water mix. Throughout the course of testing, O_3 contactor BrO_3^- ranged from <2 µg/L to 16.6 µg/L. Reservoir effluent BrO_3^- ranged from <2 µg/L to 11.9 µg/L. Although one sample was higher than the BrO_3^- MCL of 10 µg/L, BrO_3^- compliance is based on annual average of monthly samples, which was never exceeded during the testing. All other finished water reservoir BrO_3^- samples during the testing were below 10 µg/L.

BrO_3^- yield as a function of Cl_2 dose is shown on Figure 9. In this figure, results from seven tests were used to determine the optimal Cl_2 dose. Five of the seven tests showed BrO_3^- yield decrease as the Cl_2 dose approached 1.0 mg/L. Similar tests on NH_3 were performed in order to optimize the NH_3 dose (Figure 10). Unlike the Cl_2 dose, no trends were observed from the data collected. This was likely the result of problems with crystallization of NH_3 that was experienced during testing (see Additional Observations discussion below). A review of literature describing the Cl_2/NH_3 process suggested a NH_3 dose of 0.1 to 0.3 mg/L is

FIGURE 7 CO_2 Addition - BrO_3^- Yield vs O_3/TOC Ratio

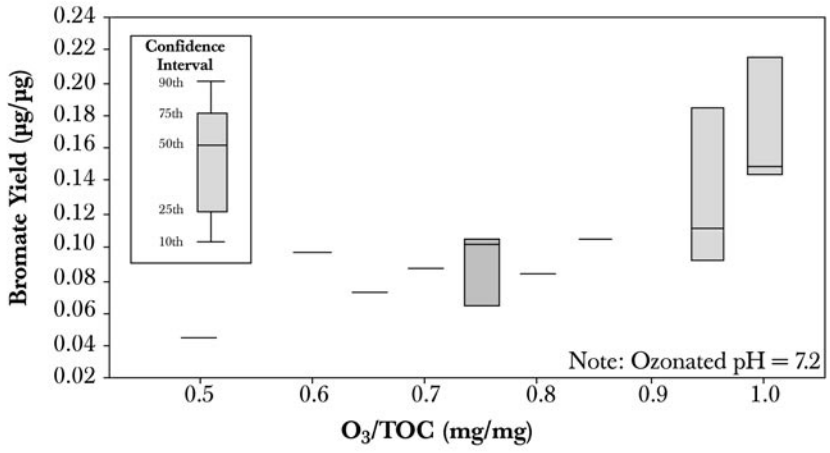


FIGURE 8 CO_2 Addition - BrO_3^- Yield vs. pH

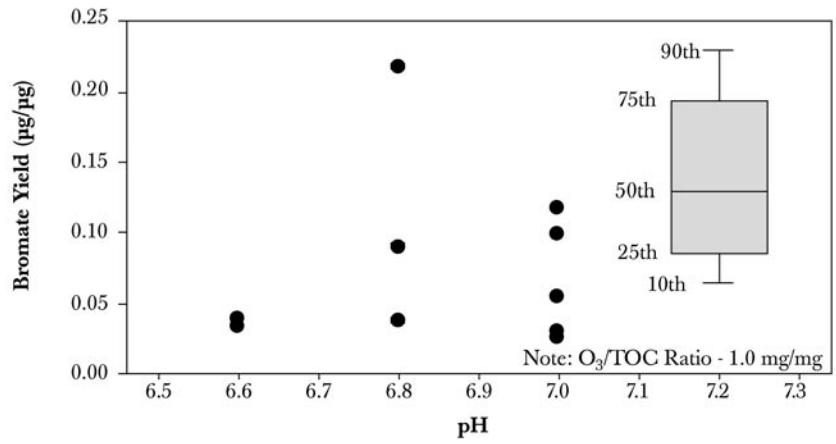


FIGURE 9 Cl_2/NH_3 Addition - BrO_3^- Yield vs. NH_3

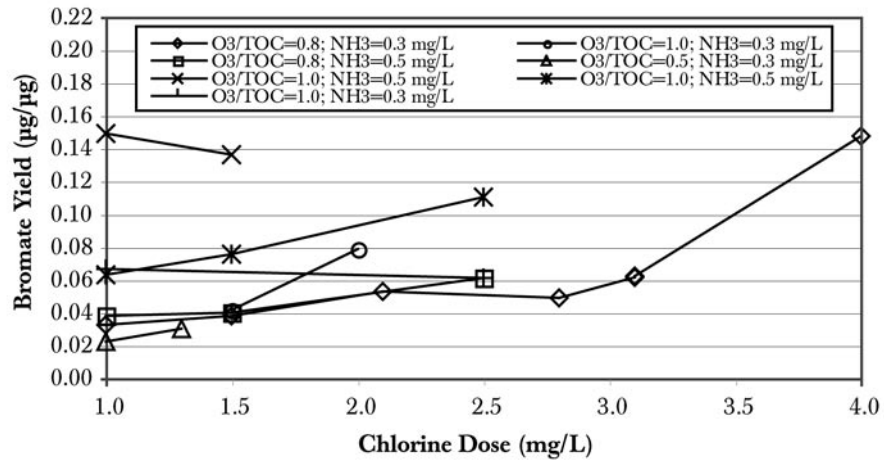


FIGURE 10 Cl_2/NH_3 Addition - BrO_3^- Yield vs. NH_3

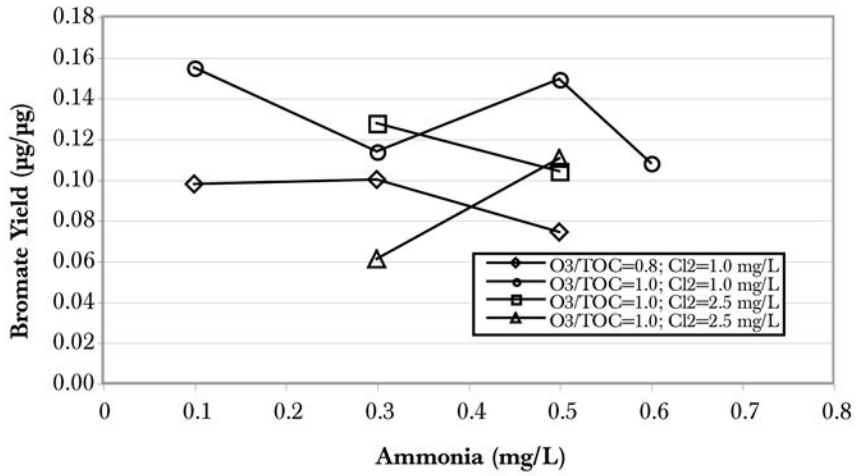


FIGURE 11 Cl_2/NH_3 Addition - BrO_3^- Yield vs O_3/TOC

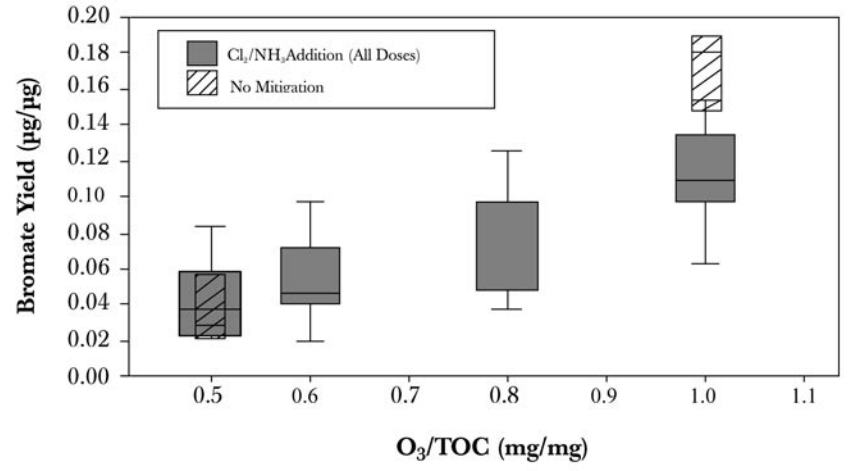
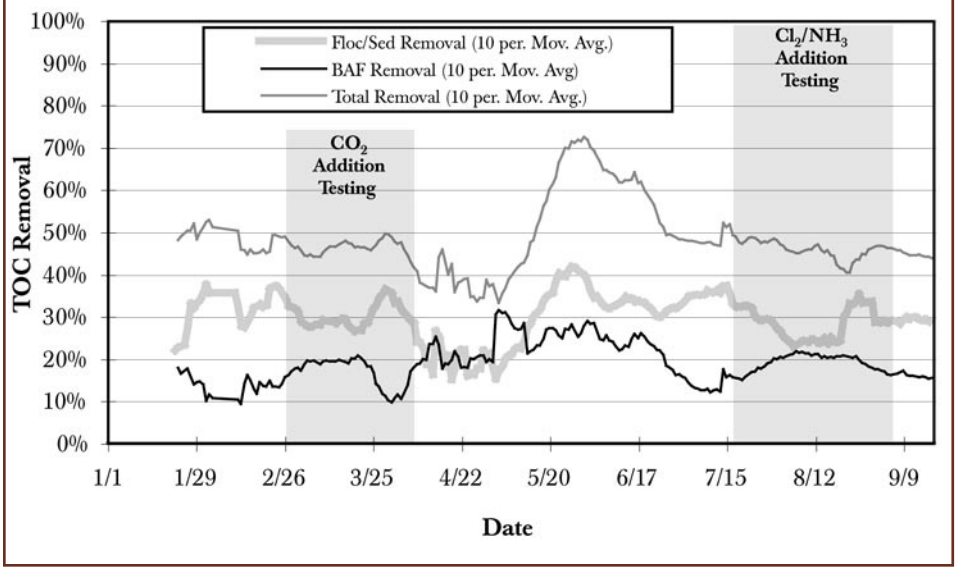


FIGURE 12 TOC Removal (2008 GWTP)



sufficient for BrO_3^- mitigation (Wert et al., 2007). Comparing the suggested literature values with the demonstration testing data, an NH_3 dose of 0.3 mg/L was selected as the optimized dose.

BrO_3^- yield as a function of O_3/TOC ratio using the Cl_2/NH_3 process is shown on Figure 11. Even though BrO_3^- yield varied with respect to Cl_2 dose and NH_3 dose, all Cl_2/NH_3 data points were used to provide a better picture of the correlation between O_3/TOC ratio and BrO_3^- yield. As expected, BrO_3^- yield increased as the O_3/TOC ratio increased. At an O_3/TOC ratio of 1.0 mg/mg, reducing Cl_2/NH_3 addition reduced the 50th percentile BrO_3^- yield from 0.18 µg/µg to 0.11 µg/µg. Applying the relationship indicated in Figure 11 to the Cl_2/NH_3 process during average GWTP raw water Br^- (100 µg/L) conditions and an O_3/TOC ratio of 1.0 mg/mg estimates bromate formation at 11-12 µg/L BrO_3^-. This would have exceeded the City's target and a lower O_3/TOC ratio would have to be applied. For BrO_3^- to be less than the 8 µg/L target in this case, the O_3/TOC ratio would have to decrease to 0.8 mg/mg.

TOC Removal. During CO_2 addition testing, raw water TOC ranged from 5.2 to 7.1 mg/L and averaged 6.1 mg/L. While higher than raw water TOC when GWTP was first commissioned in 2002 (3 to 5 mg/L), these concentrations were similar to high winter TOC that GWTP has experienced since 2004. Average removal via coagulation/ sedimentation was approximately 29 percent, 6 percent lower than observed immediately before and after testing (Figure 12). The noted drop in TOC removal via coagulation/ sedimentation was likely the result of decreased alum doses during the testing period (from 40 mg/L to 30 mg/L). TOC removal via biofiltration was approximately 20 percent, up from 10 percent immediately prior to and after testing. The increase in TOC removal via biofiltration was likely the result of the increased O_3/TOC ratio used during the testing.

During Cl_2/NH_3 demonstration testing, raw water TOC ranged from 3.6 to 6.3 mg/L and averaged 5.3 mg/L. On average, the raw water TOC was about 15 percent less than the TOC during CO_2 demonstration testing. Average removal via coagulation/sedimentation was approximately 27 percent, 4 percent lower than observed

FIGURE 13 Finished Water TTHMs (2008 GWTP)

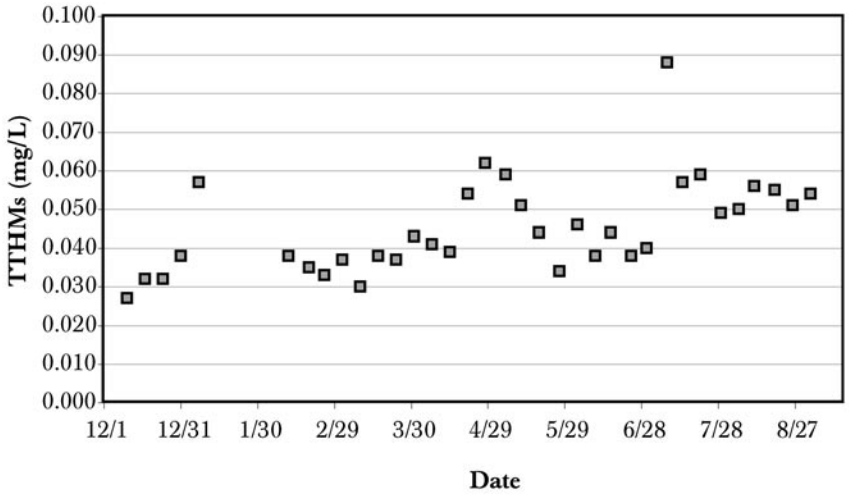
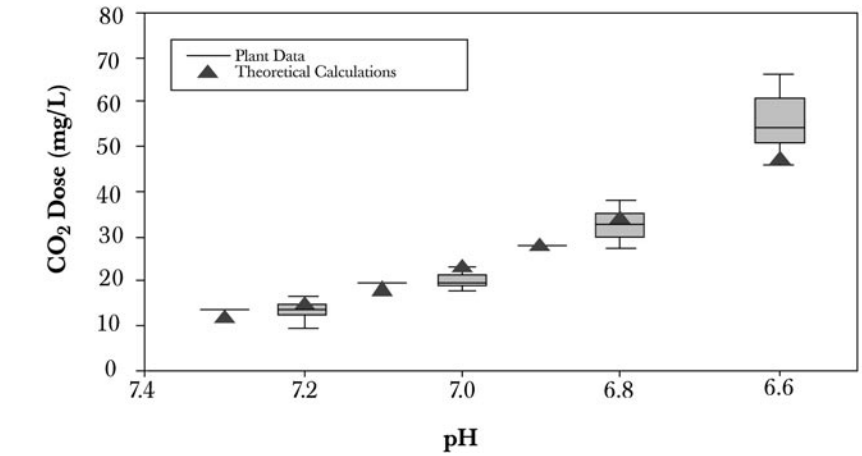


FIGURE 14 CO_2 Addition - pH vs. CO_2



immediately before and after testing (Figure 12). The noted drop in TOC removal via coagulation/sedimentation was likely the result of decreased alum doses during the testing period (from 25 mg/L to 20 mg/L). Similar to CO_2 addition testing, TOC removal via biofiltration averaged 20 percent (up from 10 percent immediately prior to and after testing). Similar to CO_2 testing, the increase in TOC removal via biofiltration was likely the result of the increased O_3/TOC ratio used during the testing.

TTHM Formation. Because Cl_2 was added earlier in the treatment process, TTHMs were monitored in the finished water to determine if the Cl_2/NH_3 process would increase TTHM formation in the plant (Figure 13). During the winter (December 2007 through March 2008), plant TTHMs averaged 35 µg/L. As the warm summer months approached, TTHMs increased to 60 µg/L. The TTHMs then dropped to 40 µg/L when GWTP replaced the GAC in two filters. On or around July 15, 2008, when adsorption had nearly finished and the Cl_2/NH_3 process commenced, a spike of almost 90 µg/L was observed, but plant TTHMs dropped and remained around 55 µg/L for the remainder of the testing period. Following the testing period, TTHMs remained around 55 µg/L. The 90 µg/L spike was likely due to the high Cl_2 doses (4.0 mg/L) initially used during the optimization period. Once the dose was reduced to 1.0 mg/L a few days later, TTHMs did not appear to fluctuate. Based on these findings, when a Cl_2 dose of 1.0 mg/L was used for the Cl_2/NH_3 process, no increases in TTHMs were observed leaving the plant compared to baseline conditions.

CO_2 Dosing. The CO_2 dose needed to achieve a desired pH is a function of raw water pH and alkalinity. During testing, the CO_2 dose was determined automatically by a pH meter located downstream of the injection point. The CO_2 flowrate, raw water flowrate, raw water pH, and pH set point were recorded every four hours by operators and used to determine CO_2 concentration as a function of desired pH, given a raw water pH of 8.0 (Figure 14). With an average alkalinity of 154 mg/L as $CaCO_3$, CO_2 dose with respect to pH was linear between pH 7.0 and 7.4. As the pH approached 6.6, however, the CO_2 dose became more exponential, requiring up to 65 mg/L CO_2 to reach a pH of 6.6. This curve obtained empirically from test data was compared to theoretical calculations performed using equilibrium calculations based on an alkalinity of 154 mg/L and raw water pH of 8.0. In the pH range of 7.3 to 6.8, the theoretical calculations were similar to the values observed during testing.

Additional Observations. After roughly two weeks of CO_2 addition testing, a thin film of algae was observed on the surface of the pre-sedimentation basin. The increased algae growth in the pre-sedimentation basin was likely due to the increased presence of CO_2 in the water. Similar algae growth was not observed in the main sedimentation basins. During the demonstration testing, the CO_2 feed point was located prior to the pre-sed basin because of the electrical constraints imposed by the CO_2 storage tank and PSF panel.

During Cl_2/NH_3 testing, GWTP operators had difficulties maintaining the temporary NH_3 feed system. Because of the ambient air temperature and distance between the chemical feed pump and injection point (>100 ft), NH_3 volatized in the pipe and air-locked the pump. Also, a few weeks after testing, operators checked the feed system piping and noted that there was significant scale build-up where NH_3 mixed with the carrier water. This was likely caused by the hardness of the carrier water. In all, the chemical feed line needed to be replaced three times and could have been the cause of some inconsistent data points obtained during testing.

Bench-Scale Testing

During the bench-scale testing, H_2SO_4 was used in lieu of CO_2 to reduce the pH.

FIGURE 15 Bench-Scale - Alkalinity and BrO_3^-

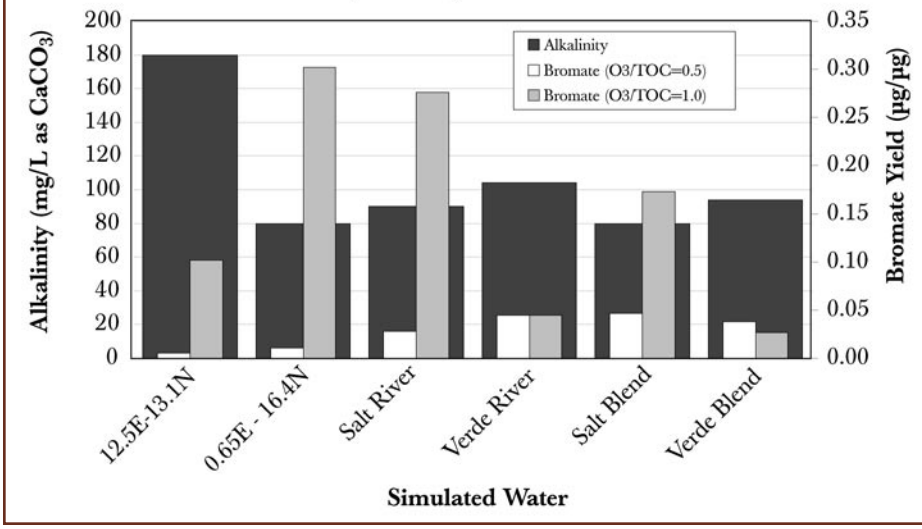


FIGURE 16 Bench-Scale - BrO_3^- Yield at O_3/TOC=05 mg/mg

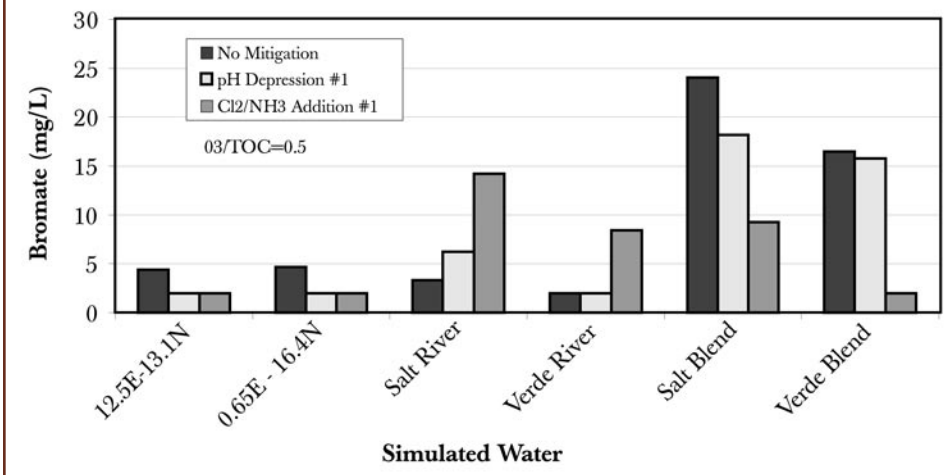
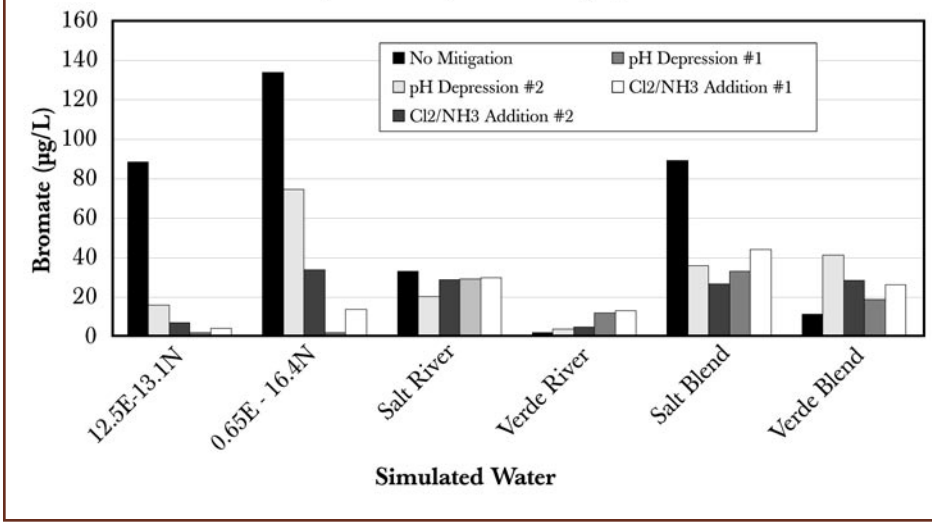


FIGURE 17 Bench-Scale - BrO_3^- Yield at O_3/TOC=1.0 mg/mg



Results from the pH lowering practices may vary slightly as CO_2 does not destroy alkalinity while the addition of acid does. Because alkalinity plays a role in ozone decay and hydroxyl radical scavenging, the effect on BrO_3^- mitigation could vary slightly (not considered significant for the purpose of this study) between these two alternatives for depressing pH.

Bromate Yield. The alkalinity and BrO_3^- yield of the simulated waters with no mitigation strategy are shown on Figure 15. Well 06.5E-16.4N and Salt River water had the highest BrO_3^- yield of all the waters (0.302 and 0.276 µg/µg, respectively) followed by the Salt River water blend. Verde River water (pure and blended) had the lowest BrO_3^- yield, possibly due to the lower Br^- and higher alkalinity. Well 12.5E-13.1N had a lower BrO_3^- yield than the other well even through its Br^- was nearly double. This may have been because of the well's high alkalinity.

Figure 16 summarizes the results of bench-scale BrO_3^- mitigation testing with various waters at the O_3/TOC ratio of 0.5 mg/mg. As shown on this figure, both BrO_3^- mitigation strategies were effective on the groundwaters and surface water blends. For reasons not entirely evident, an increase in BrO_3^- formation was observed after the mitigation strategies were applied to the unblended Salt and Verde waters. Similar trends were also observed at an O_3/TOC ratio of 1.0 mg/mg (Figure 17), although it should be noted that the apparent increase in BrO_3^- from the mitigation strategies were much less prominent in the pure source waters at the elevated O_3/TOC ratio. At an O_3/TOC ratio of 0.5 mg/mg, some of the increases could have been an artifact of higher measurement variability when near the ion chromatograph's lower detection limit. At an O_3/TOC ratio of 1.0 mg/mg, when measured concentrations were considerably above the lower detection limit, the increase in BrO_3^- formation could have been attributed to the complex interaction of alkalinity and TOC to the applied O_3 dose.

The extent to which BrO_3^- forms depends not only on the moleculer O_3 and OH• radical pathway rates of reactions, but also on the complex series of reactions between O_3, OH• radicals, and other constituents. When TOC reacts with O_3, OH• radicals are formed. Be-

cause of their strong oxidative nature, if these radicals are not reduced by other constituents in the water (e.g., pathogens, organic matter, carbonate ions), they can form additional BrO_3^-. Given that these constituents will all react at different rates and to greater/lesser extents, BrO_3^- reduction may vary, as observed in this series of testing with these simulated waters.

TTHM Formation. Samples were also collected and measured for TTHMs. During bench-scale testing a small amount of TTHMs (less than 15 µg/L) had been observed to form as a result of the chlorine application that was needed for the Cl_2/NH_3 process. It should be noted, however, that because these waters were taken from the wellhead and from upstream sources, the Cl_2 demand was likely lower than GWTP raw water which would imply that more of the Cl_2 was available for THM formation compared to full-scale conditions. For this reason, full-scale data from similar tests showed no overall increase, although bench-scale testing showed a small increase in THM formation. The full-scale results were also influenced by the removal of Cl_2 demanding organics by GAC adsorption and biofiltration at the plant.

CONCLUSIONS

Based on the results of the full-scale plant demonstration and bench scale experiments, the following conclusions were drawn:

- Both pH depression (via CO_2 addition) and the Cl_2/NH_3 process were able to reduce BrO_3^- yield 35 percent or more depending on the raw water blends available at the GWTP. CO_2 addition appeared to perform slightly more consistently compared to the Cl_2/NH_3 process.
- Based on the full-scale and bench-scale testing, applying an O_3/TOC ratio of 1.0 mg/mg, neither process was expected to reduce BrO_3^- formation below 8 µg/L 100 percent of the time. CO_2 addition may not economically reduce pH below 6.8 in high alkalinity waters, and Cl_2/NH_3 addition may not produce significant BrO_3^- reduction in some surface water blends.
- During full-scale testing, Cl_2/NH_3 addition did not appear to increase overall TTHM concentrations in the finished water.
- Both BrO_3^- mitigation strategies were very effective on groundwaters. Both processes also showed promise on surface/groundwater blends, which is the most likely composition of water in the Arizona Canal. Considering their proximity to GWTP, Br^- levels, and frequency of operation, wells 06.0E-16.5N, 06.5E-16.4N, and 07.5E-15.2N had the highest potential to increase raw water Br^- levels. During ozonation, groundwater had the highest potential to form BrO_3^-, followed by Salt River Water. Possibly due to its higher alkalinity and lower Br^- levels, Verde River Water had the lowest BrO_3^- formation potential.

POSTSCRIPT

The conclusions outlined above were applied with other economic, social, and environmental decision criteria not discussed in this paper. In addition to bromate mitigation, these criteria included total present worth costs, process life cycle assessments, health and safety, operational complexity, and community acceptance. Based on these criteria, the chlorine/ammonia process appeared to be the best alternative to mitigate bromate formation while allowing higher ozone dosages and thereby enhancing taste, odor, and TOC removal.

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