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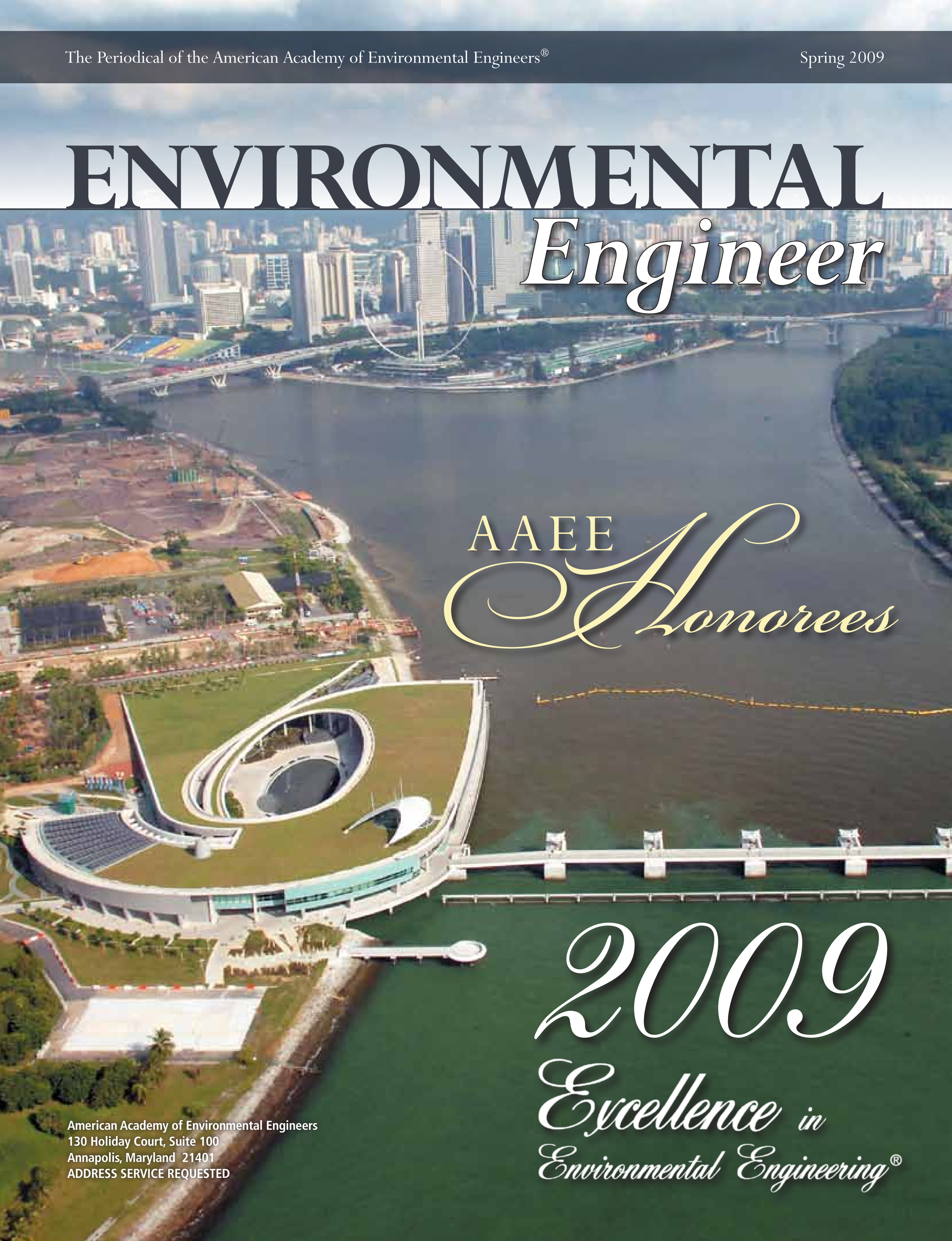
ENVIRONMENTAL Engineer



AAEE Honorees

2009 Excellence in Environmental Engineering®

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ENVIRONMENTAL Engineer

Spring 2009

FEATURES

DEPARTMENTS

COVER PHOTO: Marina Barrage, Singapore. Courtesy of CDM & PUB (Singapore's national water agency), Superior Achievement Award Winner for the 2009 E3 Competition.

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

The Diversity of Engineering

However the concept of diversity goes beyond gender or race; it includes where we come from, where we work, the media we work in, and who we help.

Over the holidays, I was catching up on my reading of the many journals, magazines, and newsletters that had accumulated over fall semester and was struck by the diverse problems that environmental engineers face today. It occurred to me that there were many facets of environmental engineering diversity. It's fairly well known that environmental engineering has the highest percentage of women of any engineering field – in 2007, 44.5 % of Environmental Engineering BS degrees were earned by women compared with 18.1% in engineering overall; less known is the fact that in 2004, 8.9% of the Environmental Engineering BS degrees went to Hispanic Americans while they obtained only 5.6 % of the overall engineering BS degrees that year. However, the concept of diversity goes beyond gender or race; it includes where we come from, where we work, the media we work in, and who we help.

I have no hard data, but based on observations of the over 70 students I have advised over the past 20 years, I would say that the vast majority of environmental engineers have bachelor degrees from other disciplines including civil engineering, mechanical engineering, agricultural engineering, chemistry, biology and many others. While this diversity makes it challenging to ensure that each environmental engineer achieves the required body of knowledge to practice environmental engineering, it brings wide-ranging skills and abilities to the equally broad professional challenges we must meet.

In developing the Environmental Engineering Body of Knowledge (EnvEBOK), the EnvEBOK task force debated long and hard as to how to address the diversity of our profession relative to how we define environmental engineering and our typical duties. We rejected the notion of traditional areas of competence such as air quality, water quality, water/wastewater transport systems, water supply and treatment, solid waste management, etc.; instead choosing to identify our areas of specialization by the nature of the contaminants we deal with, the broad systems of interest, the nature of the processes being designed, and the nature of the intervention whether it was minimization, treatment, or assimilation. We discussed emerging areas of specialization such as green infrastructure design, sustainability, ecosystem services design, and ecological risk assessment.

Back to the literature I read over my winter break; I read about a mobile solid waste processor developed by Purdue University engineers to deal with waste production by our troops in Iraq. Called the TGER, it grinds and gasifies the waste and produces a propane-like fuel. I learned about the Humanitarian Engineer who provides a connection between engineering, ethics, social justice, and sustainable development. There was an article about the intersection of water and energy and technical solutions to conserve and produce energy. I also read about a study of the effects the tourism industry has on local environments in developing countries. Recent National Science Foundation's Environmental Engineering and Sustainability Program grant awards range from environmental impacts of nanoparticles, to systems biology and engineering, to wind power, to vehicular-emitted particle dynamics, demonstrating the diversity of our challenges as well.

Most environmental engineers must consider system-wide impacts of their solutions to problems; we must see the big picture and synthesize information, societal needs, and resource conservation, something Daniel Pink in his book, *A Whole New Mind,* says requires both left and right brain thinking. A diverse labor force brings the ideal solution to these needs. In recognition of the diversity in environmental engineering, AAEE is considering a new certification category at our Spring 2009 Board of Trustees meeting — Sustainability.

If you have other ideas about how AAEE can better serve the diverse environmental engineering field, please let me know. **EE**

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By Michael Selna, P.E., BCEE, and Gary Gasperino, P.E., BCEE

SPECIAL NEWS REPORT:

Air and Waste Management Association Rejoins AAEE as a Sponsoring Organization

The AAEE Board of Trustees enthusiastically welcomed back the Air and Waste Management Association (A&WMA) as a Sponsoring Organization and approved the appointment of Gary Gasperino as A&WMA's representative at its Annual Board Meeting November 7, 2008. Gasperino also serves as Vice President of A&WMA.

BACKGROUND ON A&WMA

The Core Purpose of A&WMA is to advance the environmental profession by providing a neutral forum for knowledge exchange and networking. The Mission of A&WMA is to assist in the professional development and critical environmental decision-making of its members to benefit society.

A&WMA carries out its mission primarily through three councils: Education, Sections and Chapters, and Technical.

The Education Council manages all levels of education and training and public outreach. Education Council programs encourage adequate human resources in the fields of air and waste management and improve members' expertise. Materials are also developed to educate members and other professionals, academia, and the general public.

The Sections and Chapters Council helps to fulfill the core purpose of the Association at the local level and ensures communication between sections, chapters and Association leadership. A&WMA currently has 32 Sections and 67 Chapters worldwide.

The Technical Council supplies technical expertise for developing and participating in the Technical Program for all conferences. They also hold joint society-sponsored meetings and seminars; conduct and report on state-of-the-art studies; provide review services to government agencies and NGOs; and help provide information to guide future regulatory direction. This Council comprises three groups: Air, Environmental Management, and Resource Conservation and Waste Management. The groups include 12 divisions which are further divided into technical coordinating committees (TCCs)—the Council's workhorses. More than 1,000 A&WMA members are involved in committee work.

Boasting a 102-year record of success, A&WMA further serves the environmental profession through its monthly *Journal of the Air & Waste Management Association*, *EM*, and *The Magazine for Environmental Managers*, and through its annual international conference (scheduled this year for June 16-19 in Detroit), specialty conferences, and other professional development programs. To learn more about A&WMA and to join the association, access their website at ***www.awma.org/***.

JOINT EFFORTS

One overlapping goal of both A&WMA and AAEE is to engage in strategic alliances and partnerships and increase their value and benefits to members. As the Academy continues its efforts to engage with its Sponsoring Organizations, a workshop jointly sponsored by AAEE and A&WMA is a strong possibility.

Mike Selna and Gary Gasperino wish to recognize Professor Sam Vigil, PhD, P.E., BCEE, of Cal Poly San Luis Obispo (California), who encouraged them to work on the logistics of A&WMA as a Sponsoring Organization.

The Academy looks forward to a strong and mutually beneficial partnership with A&WMA.

Welcome Back! EE

by Joseph S. Cavarretta, CAE

Paradigms of Pivotal Change

To what extent does the American population depend upon environmental engineers? How will current and future shortages of engineers affect the environmental engineering profession?

Not long ago, I learned that in fewer than 20 years, a shortage of at least 15,000 veterinary science practitioners will occur because children are not being encouraged to pursue those careers. It didn't seem like a credible problem to me because veterinary care centers are ubiquitous in our communities. I discovered how dependent our nation is on veterinary science when AVMA Executive Vice President Dr. Ron DeHaven appeared before the House Energy and Commerce Subcommittee on Health last year to speak in support of the Veterinary Public Health Workforce Expansion Act. Dr. DeHaven said a national shortage of veterinarians is putting the food supply at risk and could hinder efforts to prevent the spread of zoonotic diseases. Salmonella is a zoonotic disease (there are dozens of them: from Anthrax to Yellow Fever), and I can't help but wonder whether the recent salmonella contaminations (e.g., tomatoes, spinach, peanuts, pistachios, etc.) that America has experienced are related to shortages of veterinary practitioners in private and public health sectors. Veterinary scientists and pathologists also protect our nation's food chain from bio-terrorism.

REALITIES IN ENGINEERING

Equally serious and immediate is a growing shortage of engineers. According to a January 2009 survey by the American Society for Quality (ASQ), the expected shortage for **all** engineering jobs by 2010 is 70,000 engineers. The study does not break down engineering into professions such as environmental engineering, however according to the Bureau of Labor Statistics, demand for environmental engineers is expected to increase by 25.4% or about 14,000 individuals from 2006 to 2016. The lion's share of increases include professional, scientific, and technical services followed by state and local government agencies, especially in areas of water supply and wastewater.

ASQ's survey also notes that 85% of children (ages 8-17) are **not interested** in engineering careers. The top reasons are 44% of children are not familiar with engineering; 30% of children say they prefer a more exciting career; and 21% lack confidence in their math or science skills. According to the survey, only 20% of parents encourage their children to consider engineering jobs. Truly, we can open up the fascinating world of environmental engineering and EnvE careers to children by working directly with schools to educate not only the students but also teachers and parents. (Look in the upcoming

Summer 2009 issue of *Environmental Engineer* for an article by AAEE Board of Trustee Mike Selna about his experience with 150 students at Patrick Henry High School, San Diego.)

Clearly, the engineering industry must double or triple its efforts to promote the engineering profession in K-12 and beyond. We also must be cognizant that with the skyrocketing growth of minority populations, what worked in the past will not work today nor in the future.

IMPACT IS UNCLEAR

To what extent does the American population depend upon environmental engineers? How will current and future shortages of engineers affect the environmental engineering profession? An even more pressing question: How significantly could shortages of environmental engineers affect public health and safety? For example, when contaminated peanut butter products were distributed nationally, hundreds became sick and three people died. Of course, the peanut products were recalled, which likely saved many thousands from becoming ill or worse. Problematic environmental engineering issues could likely affect large swaths of local and regional populations. Up until now, we have managed to avoid such scenarios.

The memberships of most engineering associations generally represent a large percentage of eligible prospects. What about AAEE? Sticking strictly with professional licensed engineers for the moment, there are at least 60,000 environmental engineers in the U.S. who are eligible to apply for BCEE/DEE certification. As of 2008, AAEE counted 2,457 Board Certified Environmental Engineers—or 4.1% of the total population. Suffice to say, if AAEE was to double its membership tomorrow, it would only constitute 8.2% of all eligible engineers. In an industry where supply is falling and demand is increasing, 8.2% will hardly meet America's needs, much less global needs.

AAEE'S CHALLENGE

Clearly, AAEE needs to grow. According to management expert Gary Hamel[1] "You should only change as fast as you need to, but that is still faster than most organizations are capable of today." While AAEE cannot hope to certify 50% of those 60,000 environmental engineers next year, a sea change is necessary to create and sustain robust growth at AAEE and ensure a supply of verifiable environmental engineering experts who can meet the escalating public health needs of today and tomorrow.

Hamel says the key success is to define a clearly understood "pivot" around which change can happen. "A moral imperative or deeper purpose. A widely held set of values, or an enduring concept or idea."

AAEE is working to define its "pivot" and set the stage for our 2010 membership recruitment campaign. All AAEE members and Sponsoring Organizations will be encouraged to participate. Please share your thoughts and guidance on what you believe the central theme of AAEE's pivot for change should include. Email jcava@aaee.net. EE

1. PP 36, *Associates Now*, April 2009, American Society of Association Executives

Officer Nominees for 2010

The Academy's Nominating Committee is chaired by William P. Dee. It's members include Pasquale S. Canzano, Tapas K. Das, Brian P. Flynn, Hector R. Fuentes, Jeffrey H. Greenfield, Stephen R. Kellogg, Michael W. Selna, and Sandra L. Tripp. The committee recommends the following slate of candidates:

President Elect	Brian P. Flynn, P.E., BCEE
Vice President	Matthew Dominy, P.E., BCEE Michael W. Selna, P.E., BCEE
Trustee-at-Large	Brian D. Buckley, P.E., BCEE R. Tim Haug, Ph.D., P.E., BCEE Ronald D. Neufeld, Ph.D., P.E., BCEE James F. Stahl, P.E., BCEE

President-Elect

Brian P. Flynn, P.E., BCEE, is an environmental/chemical engineer with 37 years of environmental engineering and business experience. He holds three P.E. licenses (Texas, Louisiana, and Delaware) and earned an MS in environmental/chemical engineering at UConn in an EPA sponsored program. He is a nationally recognized expert in wastewater treatment, solid and hazardous wastes, and the management and operating practices of environmental consultants.

A Diplomate since 1981, Mr. Flynn is very active in the Academy. He currently serves as the Academy's Assistant Treasurer, Chairs the User Outreach Committee and has led the effort to develop a five-year strategic plan for the Academy. He has also developed a Financial Management course for the Academy and published *Profit Fundamentals* through the Academy's publishing arm. As a contributing editor of *Environmental Engineer*, he has also written a number of management articles for the Academy. He also the 2008 recipient of the Stanley E. Kappe award for service to his profession.

Mr. Flynn worked for the DuPont Company for eight years and then became a Founding Partner of the ERM Group, working as a consultant for 30 years. He is currently a member of the Board of Directors of ERM-New England.

During Mr. Flynn's 38 year career, he has led the development and operation of two groundbreaking technical achievements: the world's first and largest PACT wastewater treatment plant, and an innovative hazardous waste perched bed land treatment facility at a major refiner. His wastewater experience includes NPDES permitting, expert witness testimony, design and operations of municipal and industrial wastewater treatment plants, and lab and pilot scale treatability studies. Hazardous waste activities include RCRA permitting, design of landfills, innovative use of statistics to analyze environmental data, and numerous ground water contamination studies. His clients include refiners, chemical plants, steel mills, Department of the Army, and DOE's Los Alamos and WIPP sites.

Mr. Flynn has taught project and financial management training seminars worldwide and has provided management consulting to poorly functioning firms. He is the author of over two dozen papers and recently wrote the book *Profit Fundamentals*.

His extensive background in the technologies of our profession, his long involvement with Academy matters and personal management of complex organizations are ideally suited to the current needs of the Academy.

Vice President

A native of Long Island, New York, **Matthew Dominy** received his B.S. in Civil Engineering in 1969 from Bucknell University. Upon graduation, was commissioned into the Army Corps of Engineers, and served for 10 years, until 1980. His service included tours in Vietnam, Germany, Graduate School at the University of Florida, and three years in Washington, DC.

Upon leaving the Army, Mr. Dominy worked for a subsidiary of the American Can Company in South San Francisco, California, managing a metal recycling plant that converted tin-plate scrap into detinned steel, and refined, pure tin. The plant was closed in 1983, and Mr. Dominy began working in the public works field, both in the public and private sectors. That service included two years as Public Works Director for Salisbury Township, PA, eight years at the City of Torrington, CT, during which time he was recognized by the American Public Works Association as one of the Top Ten Public Works Directors in North America, and two-and-a-half years at Alachua County Florida. The common thread through all of these positions was the management of solid waste operations, from the perspective of collection, recycling, reuse, and disposal. From 1991-1996, Mr. Dominy also served on the Board of Directors of the Connecticut Resource Recovery Authority, which was responsible for solid waste management for most of the state of Connecticut.

Mr. Dominy is currently a Vice president with HNTB Corporation in Washington, DC, where he is assisting the District of Columbia with rebuilding the South Capitol and 11th Street bridges across the Anacostia River, as part of the implementation of the Anacostia Waterfront Initiative.

Mr. Dominy has been a Diplomate since 1996, serving as the APWA Trustee from 1999-2002, and as the Academy Treasurer from 2002 until 2005. Mr. Dominy was awarded the Stanley E. Kappe Award by the Academy in 2007.

Michael W. Selna, P.E., BCEE is the former Assistant Chief Engineer/GM of the Los Angeles County Sanitation Districts, an agency providing wastewater collection/treatment and solid waste management for 5.2 million constituents. He served on the staff of the Sanitation Districts for 36 years after earning a B.S. in Civil Engineering at UC Berkeley in 1970 and an M.S. in Environmental Engineering at UC Davis in 1973. His career included wastewater research, solid waste operations, and oversight of design and construction of $100 million/year of wastewater and solid waste infrastructure prior to his executive management role.

Mr. Selna has a keen interest in stimulating young people to become Environmental Engineers. He is Chairman of Environmental Engineers of the Future (E2F), a non-profit organization providing funding for Masters Degrees in Environmental Engineering. E2F, a partnership among agencies and firms involved in water, wastewater, and solid waste management linked to 65 universities, has provided $940,000 to students.

Elected to the Academy Board of Trustees (BOT) in 2006, Mr. Selna has served on the following committees: Planning, Finance, Sustainability, Engineering Education, and the Executive Committee. In 2008, he orchestrated AAEE workshops at WEF's Sustainability Specialty Conference, WEFTEC, and AWWA's National Conference, and organized an AAEE regional meeting on California's water crisis that drew 125 attendees, all to further the Academy's strategic plan. He also worked with representatives of A&WMA to help re-establish them as a Sponsoring Organization of AAEE, which the BOT approved.

Mr. Selna is committed to strengthening the Academy's reputation as the foremost certifying organization for Environmental Engineers through continued implementation of its strategic plan, growth in membership, enhanced demand for BCEEs and BCEEMs, collaboration with educators, attention to changing demographics, and inclusion of students.

Trustee-At-Large

Brian D. Buckley, P.E., BCEE, is a civil/environmental engineer with 36 years of experience in planning and design of large water and wastewater facilities and infrastructure projects all with CDM. He received his B.S. in Civil Engineering in 1973 from UMASS Amherst and his M.S. in Civil Engineering in 1980 from Northeastern University. He has been an active member of the AAEE since 2002. He has been the AAEE Massachusetts State Representative for the past six years and oversaw the exams for over 60 new members of AAEE.

During Mr. Buckley's 36 year career, he has led numerous diverse teams of engineers from various disciplines to deliver complete solutions to numerous water and wastewater clients of CDM. As program manager for the City of Cambridge MA Water System Capital Improvement Program, Mr. Buckley managed over $150 million of system improvements over 20 years. The largest single project in this program was the $80 million new Walter J. Sullivan Water Purification Facility built in 2001. Also included in the Cambridge program was the $16 million Payson Park Reservoir Reconstruction Project. In addition and also part of this program, Mr. Buckley managed the design and construction of numerous interim improvements to the existing water treatment plant that were required to ensure compliance with existing water quality regulations until the new facilities were designed and constructed. Since the City of Cambridge took a holistic approach to upgrading their facilities during this period, the program also included design and construction of upgrades to all the water reservoir gatehouse structures, dams, and their associated underground infrastructure. Both the WTP and the Payson Park Reservoir Projects were ACEC award winning projects.

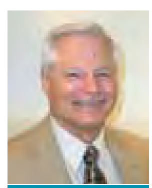
During his career at CDM, Mr. Buckley was also involved with projects such as the Prospect WTP for Sydney, Australia, the wastewater treatment plant expansion in Bedok, Singapore, the Pyramids wastewater pumping station in Cairo, Egypt, along with numerous water and wastewater projects in New England.

Mr. Buckley was also CDM's Resource Manager for 10 years helping to expand and run the operations in the Cambridge Office from the 1990's into the 2000's.

Mr. Buckley was involved with the initiation, operations and the expansion of CDM's operation in Dublin, Ireland. This office is a key office in CDM's platform for the overall European Operation. While involved with the Dublin Office, he was the Group Leader for the staff identifying and hiring new graduates from local engineering schools and introducing them to the CDM culture. He is a member of the Irish/American Chamber of Commerce and has been asked to sit on the Executive Committee. He has also been very helpful in landing some key projects for CDM in Ireland.

Mr. Buckley is currently the design leader for a several hundred million dollar project to design facilities and infrastructure at an undeveloped 450-acre site in Central Europe for the Missile Defense Agency. This highly complex work was in support of a critical Department of Defense mission to protect the U.S. from missile based threats.

Mr. Buckley is a member of the AWWA, NEWWA and the MWWA. Mr. Buckley has written several papers on his projects and presented them at the NEWWA.



R. Tim Haug, Ph.D., P.E., BCEE, received a BS degree in civil engineering from Loyola Marymount University (LMU) in 1967 and MS and PhD degrees in environmental engineering from Stanford University in 1971. Upon graduation from Stanford, he joined the LMU faculty in the Department of Civil Engineering and Environmental Sciences. He is now Professor Emeritus at LMU, teaching part-time in environmental and applied microbiology. He is a licensed professional engineer in the State of California.

Tim has authored over 120 publications on a variety of engineering and management subjects. He is author of the books *Compost Engineering – Principles and Practice* (1980) and *The Practical Handbook of Compost Engineering* (1993). He has served on the Editorial Board for BioCycle, Journal of Composting and Recycling since 1988 and on the Water Environment Federation's Editorial Advisory Board for the Biosolids Technical Bulletin. He is the 2008 recipient of the U.S. Composting Council's Rufus Chaney Award for research excellence and service to the composting industry. He became a Diplomat of the American Academy of Environmental Engineers in 2001 and is the 2008 recipient of the Academy's Gordon Maskew Fair Award.

Tim is currently Deputy City Engineer with the Bureau of Engineering, City of Los Angeles. He oversees 250 people who implement the City's Wastewater Capital Improvement Program. In this role, he has worked with teams of people who stopped ocean disposal of sludge and implemented beneficial use of biosolids in the 1980's, expanded the wastewater system to full biological treatment in the 1990's, and implemented thermophilic digestion and pasteurization to achieve exceptional quality status for the City's biosolids in the early 2000's. Today, these teams are rebuilding the secondary sewer system and major outfall sewers, enhancing water reuse by microfiltration and reverse osmosis treatment, and retrofitting the City's water reclamation plants for nutrient removal. In 2000 and 2004, Bureau projects won the Academy's award for Superior Achievement and Excellence in Environmental Engineering.

Tim's father and father-in-law were both engineers. He and Peggy, his wife of 40 years, raised two sons both of whom are engineers. They are now happily counseling their five grandchildren, hoping to continue the engineering tradition.

Ronald D. Neufeld is Professor of Civil and Environmental Engineering at the Swanson School of Engineering, University of Pittsburgh, and holds a joint appointment as Professor of Environmental and Occupational Health at the Pitt Graduate School of Public Health. He served from 1983-1984 as a Visiting Professor and Senior Fulbright Scholar at the Hebrew University of Jerusalem, where he joined a research team looking at water and waste issues relating to oil shale development. Ronald holds a BE in Chemical Engineering from Cooper Union, a MS in Chemical Engineering from Northwestern University, and a PhD in Civil (Environmental Health) Engineering from Northwestern University.

Ronald and his students have contributed over 150 papers, proceedings and presentations to the technical literature with a general emphasis on innovations in industrial and municipal wastewater treatment technologies. He was first Director of the School of Engineering "Green Construction and Sustainable Development" Program, Co-Director for the "Dominion Center for Environment and Energy", and former Chair of the University of Pittsburgh chapter of Sigma Xi.

Ronald's service to AAEE includes his current service on the Education Committee (1992-present) and the Academy User Outreach Workgroup. He continues to serve as the AAEE ABET Program Evaluator for Environmental Engineering. He currently serves as Vice-Chair of the PA-Department of Environmental Resources "Cleanup Standards Science Advisory Board", Chair of the Education Committee of the ASCE Energy Division, and as Past Chair of the ASCE Energy Division Executive Committee. He is an Associate Editor of the ASCE Journal of Energy Engineering, and member of the Water Environment Federation Industrial Waste Committee, and WEF Program Committee (Industrial Waste Symposia). He was a member (1992-2001) of the US-EPA "Effluent Guidelines Taskforce", and the "Science and Technical Committee" of the Allegheny County Health Department's 3 Rivers Wet Weather Demonstration Program.

Ronald's awards include the Pennsylvania Water Environment Association Professional Research Award, ASCE Outstanding Service Award, Roy F. Weston Award and a William Kepler Whiteford Professorship.

James F. Stahl is the recently retired Chief Engineer and General Manager of the Sanitation Districts of Los Angeles County and now serves as a Vice President and Senior Technical Advisor for MWH Americas (MWH). The Districts provide wastewater treatment and solid waste management needs for approximately 5 million people and 1400 major industries. He was a member of the agency's engineering staff for 38 years, serving in various technical and managerial assignments involving wastewater research, operations, treatment plant design and solid waste. He retired from the Districts in 2007. At MWH Mr. Stahl has been an advisor to municipal clients across the United States in formulating strategies for cost effective and environmentally responsible wastewater infrastructure. His career has involved the planning, implementation and operation of a vast array of sustainable, innovative environmental engineering projects and programs. These have included a 400 mgd high purity oxygen activated sludge system, comprehensive odor control technologies, diverse biosolids handling and recycling elements, water reclamation and reuse systems, biogas energy and alternative fuel plants, state of the art materials recovery facilities and landfills, and unique public education programs.

Mr. Stahl holds a B.S. in Civil Engineering from Loyola Marymount University, a M.S. in Environmental Engineering from Stanford University, and a California P.E.. He has served on the Program and various technical Committees of the Water Environment Federation; is past Chairman of the Board of Directors of the Water Environment Research Foundation; past President of the California Association of Sanitation Agencies and a member of the National Academy of Engineering. He has been a AAEE Diplomate since 1982, and is the recipient of the Academy's Edward J. Cleary and Gordon Maskew Fair Awards. EE

The American Academy of Environmental Engineers

Honorees

2009 Stanley E. Kappe Award Recipient: *Stephen P. Graef, Ph.D., P.E., BCEE*

Steve Graef received a BS degree in Civil Engineering from Valparaiso University and an MS in Environmental Health Engineering at the University of Cincinnati. He earned a Ph.D. in Environmental Systems Engineering from Clemson University. Following graduation, he joined the Metropolitan Water Reclamation District of Greater Chicago and progressed to Operations Manager of its Stickney Plant. He joined the expanding Milwaukee Metropolitan Sewerage District as Director of Operations. During that time he was part of the upgrade of both wastewater treatments, the deep tunnel for wet weather flow and the addition of the AgriLife biosolids product to the well known Milorganite product line. In 1992, he became Director of Technical Services for Western Carolina Regional Sewer Authority, now know as Renewable Water Resources, in Greenville, SC. His focus was to consolidate 27 wastewater treatment plants into eight regional tertiary treatment plants with biological nutrient removal and to significantly improve a problematic NPDES compliance record to one achieving numerous NACWA Gold Awards.

Dr. Graef chaired WEF's Technical Practices, Education and Utility Management Committees. He served on the Executive Committee of WEF and was its Trustee to AAEE. He is an AAEE environmental engineering program evaluator for ABET accreditation, a member of the Awards Committee and coordinator of the AAEE booths at recent WEFTEC Conferences. He has served on AWWA QualServe peer review teams, has been an adjunct professor at Illinois Institute of Technology and Clemson University and is a recipient of WEF's Harrison Prescott Eddy medal. He retired from Renewable Water Resources this year and is continuing in the profession by establishing an environmental engineering consultancy specializing in utility engineering and operations. **EE**

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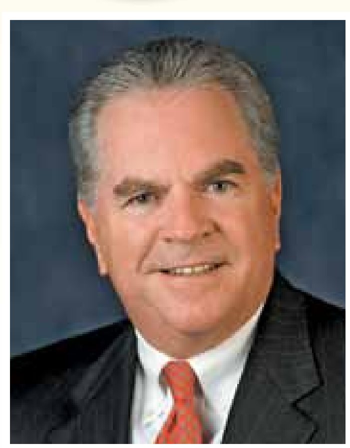
2009 Gordon Maskew Fair Award Recipient: *Thomas E. Wilson, Ph.D., P.E., BCEE*

Dr. Wilson received his Bachelor's degree in Chemical Engineering and Master's in Environmental Engineering from Northwestern University, Evanston, IL; and a doctorate in Environmental Engineering from Illinois Institute of Technology in Chicago. He is a Board-Certified Environmental Engineer and a member of the Academy since 1982, as well as a licensed Professional Engineer in three states. He is recognized as a wastewater treatment plant process expert throughout the United States, Europe, and parts of Asia, including China. He has more than 40 years of continuous experience in education, research and development, and practical application of knowledge. He served as Assistant Professor of Sanitary Engineering at Rutgers University, led process engineering for Greeley & Hansen for over 24 years and has spent the last 14 years as a technology leader for AECOM Technical Services, Inc. (ATS, formerly Earth Tech), helping the firm become a pre-eminent wastewater treatment design firm and an industry leader in nutrient removal. He is currently a Principal with ATS. He has authored or co-authored more than 160 publications and presentations, as well as two editions of a textbook, and has contributed to several manuals of practice, including serving as liquid treatment volume leader for Water Environment Federation's (WEF's) current edition of Design of Municipal Wastewater Treatment Plants and task chair for WEF's current Clarifier Design manual. He is a former editor of WEF's research journal, Water Environment Research, and was the editor of conference proceedings for the 1998 ASCE Water Resources and the Urban Environment conference. EE

2009 Edward J. Cleary Award Recipient: *Walter J. Bishop, P.E., BCEE*



Mr. Bishop's career as an engineer and leader in the water and wastewater industry spans 35 years. He is currently General Manager of the Contra Costa Water District (CCWD), one of the largest water utilities in California. Under Mr. Bishop's leadership, the District's $600 million Los Vaqueros Reservoir was completed in 1997, the first major reservoir in California in a decade, receiving the 1999 ASCE Outstanding Civil Engineering Achievement Award. He has held various positions at utilities on east and west coasts, and has been an international consultant for USAID and World Bank projects in Thailand and China.

Mr. Bishop is known for his active leadership, serving on the Board of Directors for numerous professional and utility associations, most recently 12 years as a Board Member and Chairman of the American Water Works Association Research Foundation.

Mr. Bishop helped form the Water Environment Research Foundation and served on its Board for eight years. He was a two-term member of the National Drinking Water Advisory Council, chartered by Congress to advise on drinking water policy. He led the establishment of the Utility Leadership Center at the University of North Carolina School of Business, and chaired its Governing Committee

Mr. Bishop has received: the AWWA Management and Fuller Awards, the American Public Works' Charles Nichols Award, the Association of Metropolitan Sewerage Agencies President's Award, the American Association of Environmental Engineers Featured Diplomat, the American Society of Civil Engineers (ASCE) 2003 Award for Achievement in Environmental Engineering, Duke University Distinguished Engineering Alumnus. Mr. Bishop's advocacy for restoring California's Sacramento-San Joaquin Delta has led to statewide and national recognition as a distinguished leader. EE

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2009 Honorary Board Certified Environmental Engineer: *Perry McCarty, Ph.D.*

Perry L. McCarty, Silas H. Palmer Professor Emeritus, joined the Stanford University faculty in 1962 when he came to develop the environmental engineering and science program. From 1980 to 1985, he was Chairman of Stanford's Department of Civil and Environmental Engineering, and from 1989 to 2002 served as Director of the Western Region Hazardous Substance Research Center. He has a B.S. Degree in civil engineering from Wayne State University (1953), and M.S. (1957) and Sc.D. (1959) degrees in sanitary engineering from M.I.T.

The focus of his research and teaching has been on water with primary interest in biological processes for the control of environmental contaminants. His early research was on anaerobic treatment processes, biological processes for nitrogen removal, and water reuse. Current interests are on aerobic and anaerobic biological processes for control of hazardous chemicals, advanced wastewater treatment processes, and movement, fate, and control of groundwater contaminants.

He was elected to membership in the National Academy of Engineering in 1977 and the American Academy of Arts and Sciences in 1996. He has received numerous awards, the most notable being the John and Alice Tyler Prize for Environmental Achievement in 1992, the Athalie Richardson Irvine Clarke Prize for Outstanding Achievements in Water Science and Technology in 1997, and the Stockholm Water Prize in 2007. Prof. McCarty has over 350 publications, and is coauthor of the textbooks, *Chemistry for Environmental Engineering and Science* and *Environmental Biotechnology - Principles and Applications.* EE

Honorary Board Certified Environmental Engineer: *Michael J. Rouse*

Michael Rouse offers expert independent advice on water industry matters. He has extensive knowledge and experience of water governance and regulation, including all aspects of audit and enforcement, and the governance issues related to both public sector management and privatisation. Michael is experienced in working with ministers, senior government officials, and water and sewerage utility managers, both in the UK and around the world. He has wide knowledge of water technical and operational matters, based on his applied research and development background.

He has a good understanding of international water matters and is a Past President of the International Water Association (IWA), a member of the IWA Council of Distinguished Water Professionals, and is currently chairing the Associations Group on Institutional Governance and Regulation. He is an honorary member of the American Water Works Association (AWWA). He is a Distinguished Research Associate at the University of Oxford and manages/teaches the Institutional Governance and Regulation module of the University's MSc Course on Water Science, Policy and Management. In 2000 he was awarded the CBE (Commander of the British Empire) for services to water.

His recent and current work involves projects in Ghana, China, Malaysia, Singapore, Egypt and Australia. EE



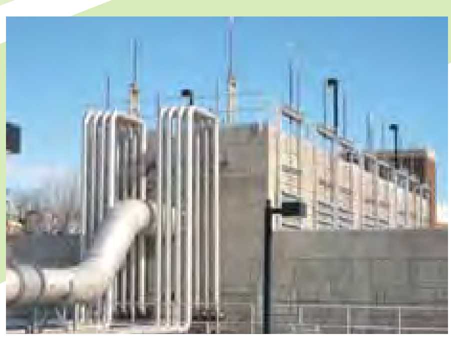
2009 Excellence in Environmental Engineering®

THE EXCELLENCE IN ENVIRONMENTAL ENGINEERING® Competition of the American Academy of Environmental Engineers exists to identify and reward the best of today's environmental engineering. Its criteria define what it takes to be the best in environmental engineering practice: a holistic environmental perspective, innovation, proven performance and customer satisfaction, and contribution to an improved quality of life and economic efficiency.

The competition, begun in 1989, is organized around the normal phases of development and implementation of environmental management projects and programs. The categories in which entrants may enter their projects are: Research, Planning, Design, Operations/Management, University Research, Small Projects, and new in 2009, Small Firms.

This year's entrants to the competition displayed a wide range of projects. At the same time, we see that today's engineers are more and more becoming significantly integrated in a team/project approach, allowing for greater flexibility and efficiency in project management. The application of new technologies combined with experienced environmental engineering practices are what make these projects distinguished award winners.

Those chosen for prizes in 2009 by an independent panel of experts, addressed the broad range of modern challenges inherent in providing life-nurturing services for humans and protection of the environment. They are but a small percentage of the many projects involving environmental engineers around the world. Nevertheless, their innovations and performance illustrate the essential role of environmental engineers in providing a healthy planet. These award winners testify to the genius of humankind and best exemplify the Excellence in Environmental Engineering® criteria.


Superior Achievement Award

Marina Barrage, Singapore

Singapore

ENTRANT: CDM & PUB, Singapore's national water agency
ENGINEER-IN-CHARGE: Robert L. Hurdle, P.E.

Singapore receives approximately 245 centimeters of rainfall annually, but still faces challenges in securing reliable water supplies for its population of 4.8 million. CDM and PUB, Singapore's national water agency, designed an integrated, sustainable solution for both flood control and water supply.

The barrage features a tidal barrage spanning across the 350 meter-wide Marina Channel; seven drainage pumps, each capable of pumping upwards of 3.5 billion liters per day; and an exhibition gallery presenting "Sustainable Singapore" in six interactive displays.

The Marina Barrage converts former port waterways into a key source of reliable freshwater — the 240 hectare Marina Reservoir. The site features an intake and 432-million liter-per-day pumping station that conveys raw, desalinated water to the island-wide water system. The barrage meets 10% of the nation's potable water demands.

Design and construction of Marina Barrage addressed complex engineering challenges — from sophisticated modeling of the water quality and hydrodynamics of Marina Reservoir, to installation of the permanent barrage structure within Marina Channel on a foundation of some 850 large diameter piles drilled to 574 meters in depth through two thick layers of marine clay.

In addition to greatly reducing the stormwater and tidal flooding in Singapore's downtown area, the barrage has proven a popular destination for residents and tourists and features a tropical botanical park which extends from downtown and along the reservoir.

The Marina Barrage was completed in July 2008, on schedule and within the US$180 million budget. Inspired by this innovative project, other coastal cities such as Hong Kong, New Orleans, and Dublin, are now interested in the concept. Dublin recently undertook preliminary studies for a tidal barrage across Dublin Bay.

TOP: *To facilitate navigation in the channel throughout the construction period, the barrage was built in two stages, the first extending west from the east abutment. As the structure neared completion, a boat hoist was built to ensure uninterrupted egress/access for small work boats and pleasure craft; allow coastguard craft to patrol the reservoir; and support major events, including the recent Formula 1 Singapore Grand Prix race and the 2008 National Day parade.*

LEFT: *The 70-tonne crest gates (as well as the 500-tonne precast bridge segments) were moved into position using floating cranes with lifting capabilities of up to 3,200 tonnes. Precision engineering was required as the tolerance level for error was only ± 2 millimeters for the centerline of the nine pivot pins of each crest gate.*

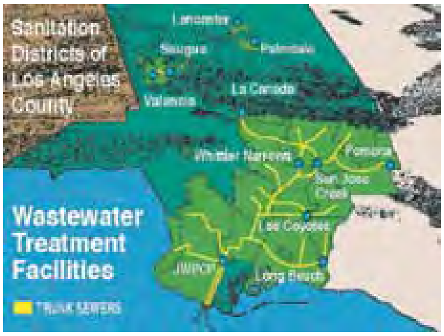
RIGHT: *Attracting 40,000 visitors during it's opening weekend, the site has proven a popular destination for local residents and tourists. Its premier location makes the reservoir an ideal venue for international water sport competitions, cultural performances, and recreational activities.*

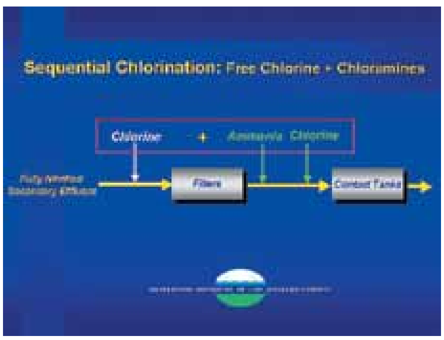
Research Grand Prize

An Innovative Approach to Disinfection for Recycled Water

Los Angeles County, California

ENTRANT: Sanitation Districts of Los Angeles County
ENGINEER-IN-CHARGE: Stephen R. Maguin, P.E., BCEE





The Sanitation Districts of Los Angeles County (Sanitation Districts) operate seven tertiary water reclamation plants (WRPs) in Los Angeles County. This past year, these seven plants produced an average of 153 million gallons per day of recycled water, of which 52 million gallons per day was reused to supplement water resources in dry Southern California. Groundwater replenishment represented about two-thirds of this water reuse.

Recycled water must be properly disinfected before reuse to protect public health. In California, disinfection requirements are specified in Water Recycling Criteria established by the Department of Public Health. Disinfection methods must be effective for pathogen inactivation and should minimize the potential generation of harmful disinfection by-products (DBPs). Historically, chlorination was the most commonly practiced wastewater disinfection technology, but research has shown that this process creates DBPs such as trihalomethanes (THMs) and N-nitrosodimethylamine (NDMA).

For groundwater replenishment, recycled water must meet drinking water standards. Although a drinking water standard has not been established for NDMA, the Sanitation Districts have proactively decided to minimize NDMA generation at its tertiary WRPs. Since 2006, the Sanitation Districts have developed, tested, and implemented a new disinfection method, called "Sequential Chlorination", at its WRPs. The advantages include high levels of pathogen inactivation, low levels of DBP formation, and the ability to be rapidly implemented. The Sequential Chlorination process has the potential to significantly reduce the size of chlorine contact tanks currently required by California regulations, thereby reducing future WRP construction costs.

The sequential chlorination process has never been used for wastewater disinfection other than at the Sanitation Districts' WRPs. The Sanitation Districts have filed a patent application for the process to keep the process in the public domain.

TOP: *The Districts provide wastewater treatment and solid waste management services to over 5 million people in Los Angeles County. For wastewater treatment, the Districts operate 11 treatment facilities with a combined treatment capacity of 510 mgd. Other than the Joint Water Pollution Control Plant (JWPCP) which is an open discharge plant, the other 10 facilities are water reclamation plants, seven of these are tertiary WRPs. These tertiary WRPs produce approximately 150 mgd of reclaimed effluent. Approximately one-third of the disinfected effluent is reused for a variety of applications including indirect potable water recharge.*

MIDDLE: *The Districts staff developed a disinfection process that applies free chlorine and chloramines sequentially to fully nitrified secondary effluents produced at their tertiary water reclamation plants. The process, named sequential chlorination, is shown on the diagram. Not only is sequential chlorination an effective disinfection process, it also minimizes the formation of various byproducts typically formed from chlorination including THMs, HAAs, cyanide, and cyanogen chloride.*

BOTTOM: *Full-scale testing was conducted at four water reclamation plants operated by the Districts. Testing included extensive sampling of disinfected effluent for analyses of various disinfection byproducts and total coliform.*

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Planning Grand Prize

ACWA Energy Independence Project

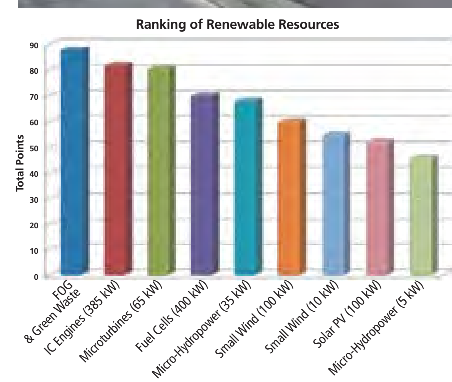
Portland, Oregon

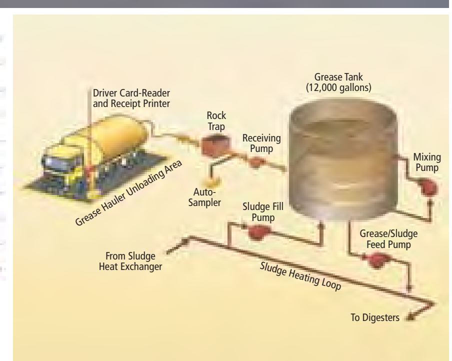
ENTRANT: Kennedy/Jenks
ENGINEER-IN-CHARGE: David D. Kennedy, P.E., BCEE

In a ground-breaking project prepared for the Oregon Association of Clean Water Agencies (ACWA), and funded by Oregon Energy Trust, Kennedy/Jenks Consultants prepared a report that provides the expertise, tools, and methodology that will allow wastewater treatment plants (WWTPs) to increase energy efficiency and implement renewable resource alternatives to eliminate their need to buy electricity.

Kennedy/Jenks performed energy audits at the Gresham WWTP and the Corvallis Wastewater Reclamation Facility. In their role, Kennedy/Jenks recommended energy-efficiency measures to reduce energy use; investigated seven renewable technologies that reduce or eliminate the need to buy electricity; developed a common template to summarize each resource option's features, advantages, impacts, costs, and implementation issues; led development of seven evaluation criteria, in consultation with ACWA's Technical Advisory Committee (TAC), and then evaluated each resource option using the seven criteria; weighed the results of the evaluations, converted subjective conclusions to quantitative scores, produced an overall weighted score for each resource option, and prioritized the most desirable options according to their weighted scores; applied the results to the Gresham and Corvallis WWTPs and developed a customized recommendation for each plant to become energy independent; and developed a systematic methodology that can be applied to any WWTP or other facility in the country that wants to eliminate its reliance on purchased electricity and become energy independent.

Kennedy/Jenks worked in close collaboration with Oregon ACWA, the Energy Trust of Oregon, and ACWA's technical advisory committee, which were consulted at several important stages of the project to solicit input and make critical decisions. To develop and complete the report, Kennedy/Jenks also worked closely with the staffs at the Gresham and Corvallis plants.





TOP: *The Gresham and Corvallis plants served as demonstration plants. The Gresham WWTP already uses its available digester gas in an internal combustion engine. The improvements recommended for the Gresham plant included implementing energy-efficient measures, and adding micro-hydropower, and solar PVs. The report indicated that a FOG and Green Waste Program would optimize the plant's energy profile.*

LEFT: *The Energy Independence Project recommended measures that would optimize energy-efficiency at the two plants and then assessed seven viable renewable resource options. Kennedy/Jenks consolidated a massive amount of information and developed a systematic methodology to evaluate the resource alternatives. The renewable resource options were ranked according to weighted scoring criteria as shown in this chart.*

RIGHT: *The top-ranked option was the FOG (fats/oil/grease) and Green Waste option. This was the most cost-effective option because the capital costs could be recovered in a relatively short time through substantial tipping fees that would be paid by grease and green waste haulers.*

Design Grand Prize

Broad Run Water Reclamation Facility

Ashburn, Virginia

ENTRANT: CH2M Hill
ENGINEER-IN-CHARGE: Daniel P. Lynch, P.E.

The result of a 10-year partnership between CH2M Hill and its client, Loudoun Water, the Broad Run project involved the study, pilot, design and construction of a $190 million, state-of-the-art, 11-mgd water reclamation plant that meets the most stringent water reclamation standards in the world.

The Broad Run WRF is the first large-scale application of membrane bioreactor (MBR)-carbon treatment-ultraviolet disinfection technology and the first MBR plant to simultaneously meet extremely stringent nutrient limits while providing multiple pathogen barriers to protect public heath. The Broad Run treatment process, which includes granular activated carbon (GAC), also incorporates biological and chemical nutrient removal resulting in reclaimed water which protects receiving waters from the damaging effects of eutrophication. All treatment processes are enclosed in buildings for complete noise and odor control.

In addition to providing a cost-effective wastewater treatment solution, the Broad Run WRF offers the large scale demonstration of MBR technology in a new way, advancing the industry's understanding of MBR technology and redefining viable approaches to water reclamation.

In a campus-like setting that incorporates nature trails, rain gardens, and a display of the treated effluent to increase public understanding of water reuse, the Broad Run WRF also provides a community amenity that will have long-lasting educational, aesthetic, and recreational value to Loudoun County, Virginia.

Achieving the vision for the Broad Run WRF brought together a multi-disciplinary design team led by CH2M Hill. CH2M Hill was retained as the engineer for a conceptual study, pilot plant, treatment plant design and construction management. Complementing the CH2M Hill team were design firms Black and Veatch, the influent pump station designer; and Patton, Harris, Rust, and Associates, the designer for civil and site permitting.

TOP: *Campus-like Facility. In a campus-like facility, the Broad Run WRF offers several sustainable, economic, and social benefits to the Loudoun County community.*

LEFT: *Complex Site Construction. Project met schedule requirements by constructing $190 million of complex treatment systems across five simultaneous contracts within 46 months.*

RIGHT: *Completed Facility. Broad Run Water Reclamation Facility sets a new world-wide technology standard for water reclamation and also provides a community amenity that will have long-lasting educational, aesthetic, and recreational value.*

Operations/Management Grand Prize

NYS Thruway Authority Statewide Stormwater Management Program

Statewide, New York

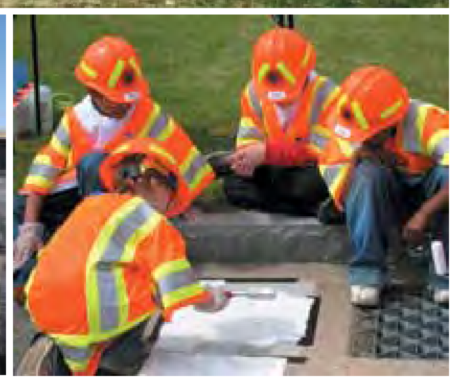
ENTRANT: Malcolm Pirnie, Inc.
ENGINEER-IN-CHARGE: Daniel J. Loewenstein, P.E., BCEE

Responding to a USEPA mandate, New York State initiated a Municipal Separate Storm Sewer System (MS4) Phase II Stormwater Permit Program to address stormwater runoff with the greatest potential to negatively impact water quality. The rule had significant implications for two major New York State agencies — the New York State Thruway Authority and the New York State Canal Corporation.

With separate storm sewer systems serving over 640 miles of roads and 524 miles of canals statewide, as well as the responsibility for extensive construction activities, the Authority and Corporation both represented one of the state's largest and most complex MS4s, requiring development and implementation of comprehensive Storm Management Programs.

Malcolm Pirnie was tasked to help these two agencies comply with the new federal and state stormwater regulations. Malcolm Pirnie developed a framework for comprehensive SWMPs to address six minimum control measures; implemented elements of the five-year SWMP (including state-of-the-art electronic data management tools); developed dozens of SWPPs to allow proposed construction projects to proceed; developed a Supplemental Guidance Manual; provided technical support and training to the Authority/Corporation designers; developed and implemented Best Management Practices (BMPs) and standard operating procedures; trained over 200 Authority/Corporation personnel statewide; conducted facility inspections and outfall mapping; developed a Stormwater Management Practice Maintenance Manual; and conducted an extensive public education/outreach/participation program.

The SWMP successfully integrates many of the agencies' existing policies and procedures and will enable the Authority/Corporation to continue to strengthen its role as an environmental steward. Public outreach and education is one of the six minimum controls required for permit compliance. The program's effective public out reach and education had the theme "Connecting the Drops" as part of this project.



TOP: *To improve communications with the public, Malcolm Pirnie and the subconsultant developed an innovative public outreach campaign, "Connecting the Drops", to educate the public at various community events, travel plazas, and the New York State Fair.*

LEFT: *The engineers worked with the Authority/Corporation to develop and implement comprehensive Storm Water Management Programs meeting the requirements of the MS4 General Permit. The engineers developed over two dozen Stormwater Pollution Prevention plans to allow construction projects like this one to proceed as scheduled.*

RIGHT: *Fourth and fifth grade students participate in a stormwater drain stenciling activity at the Thruway's Guilderland Travel Plaza — painting "Only Rain Down the Drain, Drains to Waterway" to raise awareness that storm drains drain to lakes, rivers, and streams.*

University Research Grand Prize

Production of Single Cell Oil from Cellulosic Biomass by Fungal Processing

Ames, Iowa

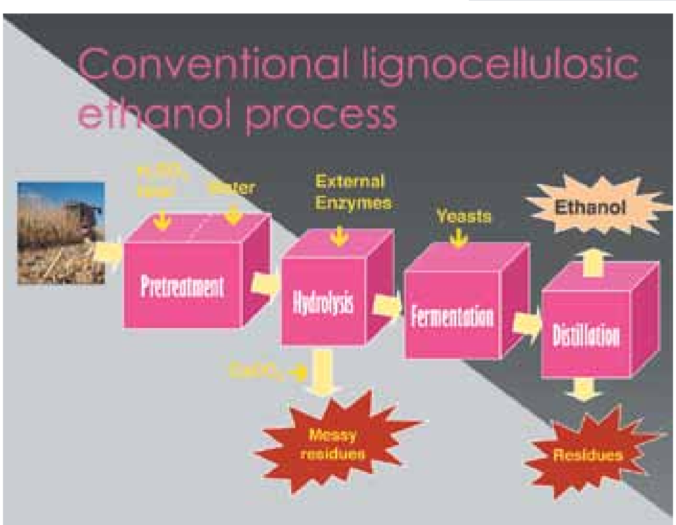
ENTRANT: Center for Crops Utilization Research, Iowa State University
ENGINEER-IN-CHARGE: J. (Hans) van Leeuwen, P.E., BCEE

Biodiesel production from traditional oil-rich crops is limited by land availability, climate, and environmental and social issues regarding the use of feed and food crops for fuel. But there's another way to produce biodiesel that is green and sustainable and doesn't compete with food crops. All it takes is some yeast — and research from Iowa State University.

Well, it's not quite that simple, said Dr. Sam Beattie, an ISU Extension food safety specialist and the yeast expert on the ISU research team. J. (Hans) van Leeuwen, a professor in the Department of Civil, Construction and Environmental Engineering, Beattie and other ISU researchers explain how they took lignocellulosic biomass — corn stover — treated it with ammonia and various wood rot fungi, then mixed it with yeast. The end results include fuel — biodiesel — protein-rich animal feed and usable co-products including lignin.

Using ammonia pretreatment and in-situ produced fungal enzymes, lignocellulosic materials were broken down to sugars and converted to oil using oleaginous yeasts, which at 60%, are easily scooped off after floating to the top.

Van Leeuwen states, "The conversion of lignocellulosic material to lipids and yeast biomass is highly economical with a payback period of 2.5 years. The facility in this cost analysis could produce 70 million lbs. of oil annually, equivalent to the oil extracted from more than 7 million bushels of soybeans, which is equivalent to 143,000 acres or 223 square miles of soybean crop. The concept is therefore very green and sustainable and not competitive with food crops. The process itself is non-polluting and carbon negative when allowing for the carbon dioxide recycled into new crops."



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Small Projects Grand Prize

Groundwater Remediation Using Enhanced Anerobic Bioremediation

Orlando, Florida

ENTRANT: CDM
ENGINEER-IN-CHARGE: Leslie A. Turner, P.E., BCEE

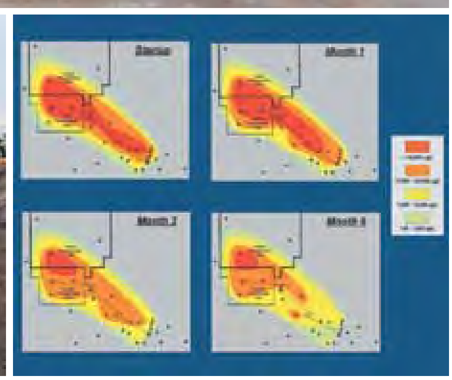
When Rockwell Automation acquired the former PEC Industries property in Orlando, Florida, shallow groundwater was impacted. Chlorinated solvents were released into the environment and leached into the groundwater. Despite exhaustive efforts over several years, Rockwell was unable to find an appropriate remediation solution until partnering with CDM.

Applying enhanced anaerobic bioremediation (EAB), in conjunction with a unique groundwater recirculation technique, rid the site of chlorinated solvents, which had leached into the groundwater. After researching several cleanup options which had all been deemed ineffective or cost prohibitive, CDM pilot tested EAB with potassium lactate and proved its effectiveness at this highly contaminated site. EAB leverages a naturally occurring bacteria present at the site, eliminating contamination in the ground and mitigating risks typically associated with extraction technologies.

CDM designed an innovative well system comprising horizontal recovery and vertical injection wells. This system injects potassium lactate into the groundwater and continuously recirculates the groundwater to ensure that lactate, bacteria, and contaminants are in constant contact — creating an environment unmatched using typical injection techniques.

The well system also controls the flow of groundwater, preventing off-site migration, and floods the contaminated zones with lactate to enhance the growth of the dechlorinating bacteria. Once lactate was added and water recirculation began, the site underwent an unprecedented bacterial population boom.

Within the first 6 months of full-scale operation, which commenced in December 2007, volatile organic compound mass was reduced by more than 90%. At startup, the highest concentration area had more than 2,000,000 parts per billion of methylene chloride. After 6 months, the methylene chloride in this targeted area had been completely remediated and has not been observed since.



TOP: *After purchasing the former PEC Industrial manufacturing facility (background), along with 9 acres of land in Orlando, Florida, Rockwell Automation explored various clean-up options to mitigate contaminated groundwater.*

LEFT: *CDM designed and built a groundwater circulation system using horizontal wells (shown) that intersect and can extract from all three surficial aquifer zones. Continually recirculating groundwater ensures that lactate, the Dehalococcoides spp. bacteria, and contaminants are in constant contact, creating an ideal enhanced anaerobic bioremediation (EAB) environment.*

RIGHT: *This table shows the reduction in total volatile organic compounds in the intermediate aquifer zone after just 6 months of EAB treatment with potassium lactate. Within the 6 months of full-scale operation, VOC mass was reduced by more than 90%.*

Small Firms Grand Prize

Onsite Nitrogen Reduction with Two-Stage Biofiltration

Thonotosassa, Florida

ENTRANT: Applied Environmental Technology
ENGINEER-IN-CHARGE: Daniel P. Smith, Ph.D., P.E., DEE

Applied Environmental Technology (AET) of Tampa, Florida, developed a treatment process that reduces nitrogen in household sanitation water by over 97%.

The AET project was funded by the Bureau of Onsite Sewage Programs of the Florida Department of Health. The Department estimates that there are 2.5 million onsite wastewater systems in Florida, the great majority of which remove only a small fraction of nitrogen. The purpose of the project was to develop systems that achieve substantially greater nitrogen removals. There is a concern in many regions of the state that untreated nitrogen from septic systems can potentially migrate to aquifers and surface waters and contribute to a decline in water quality.

To remove septic system nitrogen, Applied Environmental Technology (AET) developed a two-stage biofiltration system that reduces nitrogen in domestic sanitation water by over 97%. The process is simple, robust, and uses only a single dosing pump as its sole moving part. Its design was informed by practical experience and the judicious application of fundamental engineering concepts. Two-stage biofilter effluent is comparable in quality to that of large centralized treatment plants. The passive two-stage biofiltration system is an appropriate and sustainable technology for onsite sanitation water treatment.

Additional studies are underway to expand the findings. The biofiltration project was intended to address individual septic systems which are typically located in more rural areas. As Dr. Smith notes, "Densely inhabited areas are served by large water systems that perform well, but more sustainable approaches are needed. Biofiltration can be deployed to treat and recover sanitation water within areas served by centralized systems."

TOP: *Project site at Flatwoods Park, Hillsborough County, a popular public day-use facility serving the Tampa Florida area. Septic tank effluent originated from single family ranger residences and day use lavatory facilities; test system is to the far right.*

LEFT: *Field test sytem from south showing three parallel two-stage filter systems. Vertical columns are unsaturated media filters (Stage 1) receiving septic tank effluent at 30 minute dose intervals; horizontal columns are anoxic denitrification filters (Stage 2). Upper containment chamber contains multi-head peristaltic pump and repeat cycle dosing timer. The test system was located near a high public use area and resulted in no impairment of recreational amenities.*

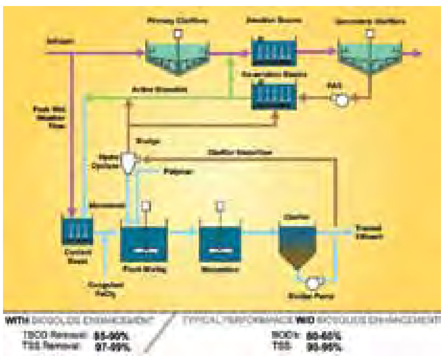
RIGHT: *Denitrification filter medium: left to right, utelite, oyster shell, elemental sulfur.*

Research Honor Award

Biologically Enhanced High-Rate Clarification

Fort Smith, Arkansas

ENTRANT: CDM
ENGINEER-IN-CHARGE: Jyh-Wei Sun, P.E., BCEE



CDM, the city of Fort Smith, Arkansas, and Kruger partnered to conduct a research project to evaluate the effectiveness of biologically enhanced high-rate clarification (BEHRC). CDM invented the process which adds active biosolids to the high-rate clarification system to increase overall biochemical oxygen demand removal. In addition to the pilot study, the firm managed the collection of samples, lab analytical testing, data analysis, quality control and assurance review, and report preparation.

Fort Smith, Arkansas, made the execution of the pilot study possible by making modifications to the city's P Street wastewater treatment facility, which included: conversion of a channel to act as the contact chamber, diffuser installation for mixing and oxygen transfer, and pump installation.

Kruger provided the trailer-mounted unit used to conduct the pilot study, consisting of a small-scale high-rate clarification system.

TOP: *The U.S. Environmental Protection Agency confirmed that BEHRC is equivalent to secondary treatment. By achieving as much as 90% total BOD removal and 99% TSS removal, BEHRC meets discharge regulations without the need for additional treatment or blending.*

BOTTOM: *BEHRC Process: CDM invented the biologically enhanced high-rate clarification (BEHRC) process to increase biochemical oxygen demand removal achieved by HRC alone.*

Planning Honor Award

Enhanced Use Lease Development at Hill AFB

Ogden, Utah

ENTRANT: Malcolm Pirnie, Inc.
ENGINEER-IN-CHARGE: Donald W. Clause, P.E., BCEE

Malcolm Pirnie was hired as the principal advisor by the U.S. Air Force to plan, prepare, and execute an Enhanced Use Lease (EUL) of approximately 550 acres of non-excess and underutilized real property at Hill Air Force Base, UT.

The project arose from the need to replace over 1.2 million square feet of insufficient office space – quickly deteriorating World War II era warehouse facilities converted to offices, housing numerous tenant and command entities in substandard, inefficient space. Replacing or rehabilitating old buildings through traditional Military Construction funding would have cost hundreds of millions of dollars without eliminating existing inefficiencies.

The project included a market analysis and economic and concept feasibility study to determine the project's financial feasibility and provide an attractive real estate opportunity for developers. Malcolm Pirnie led all phases of this project from concept plan to development selection and negotiation assistance.

TOP: *World War II era warehouse and office building at the Hill AFB. The Air Force identified the need to replace over 1.2 million square feet of similarly deteriorating facilities. Housing numerous tenant and command entities in these substandard inefficient spaces reduced organization effectiveness while increasing maintenance and utility costs.*

BOTTOM: *Artists rendering of proposed new development. Malcolm Pirnie began the project by writing a Business Case Analysis to help determine the project's feasibility and analyzing its value; together with the Air Force, Pirnie determined the land's Fair Market Value to be $10 million. The developer was selected through a full and open competition to achieve the best value for the Air Force.*

Design Honor Award

Back River Wastewater Treatment Plant

Baltimore, Maryland

ENTRANT: AECOM
ENGINEER-IN-CHARGE: Ralph B. "Rusty" Schroedel, P.E., BCEE and Michael J. Zapinski, P.E.

The Back River Wastewater Treatment Plant is the larger of the two treatment plants owned and operated by the City of Baltimore, Maryland. It is a secondary wastewater treatment facility incorporating the activated sludge process. The City's Energy Office was interested in selecting an energy services company (ESCO) capable of developing and delivering a performance contract to utilize the digester gas that was also experienced in wastewater treatment. The team of Johnson Controls with subcontractor AECOM (formerly Earth Tech) was selected because they had a history of service to the City of Baltimore, and of working together.

AECOM provided engineering services during the study, preliminary design and final design/construction document phases of the Back River WWTP cogeneration facility. Cogeneration refers to the process of using a single plant to generate electricity and useful heat. The final design consisted of an electrical cogeneration plant that uses internal combustion engines fueled by the digester gas that was previously flared.

TOP: The gas conditioning building (at center) and engine/generator building (at right) were constructed to be both functional and aesthetically pleasing. The renowned egg shaped digesters can be seen in the background.

BOTTOM: The site for construction of the new facility was placed in the location of an abandoned pad for a past attempt to use the excess digester gas. Some of the gas flares are visible in the foreground.

Design Honor Award

Twin Oaks Valley Water Treatment Plant DBO Project

San Marcos, California

ENTRANT: CH2M Hill
ENGINEER-IN-CHARGE: Daniel P. Wetstein, P.E., BCEE

The Twin Oaks Valley Water Treatment Plant is one of the largest treatment plants in the world to use submerged membrane technology to produce high-quality drinking water. The plant — San Diego County Water Authority's first treatment plant to build and own — was constructed under a design-build-operate contract by CH2M Hill. The high capacity plant provides enough water to serve approximately 220,000 households per year.

The need for an additional water treatment facility in the region was realized because a single treatment plant, owned and operated by another water district, provided most of the region's treated water; and had been operating at or near capacity for several years. The Water Authority decided on the design-build-operate approach to reduce the overall cost of construction and allow for a rapid construction schedule. The 100 mgd plant was operational only 30 months after contract execution — providing the Water Authority's customers with a new source of water in time for the high-demand summer season.

TOP: The Twin Oaks Valley Water Treatment Plant is located on 11 acres of a 45-acre site.

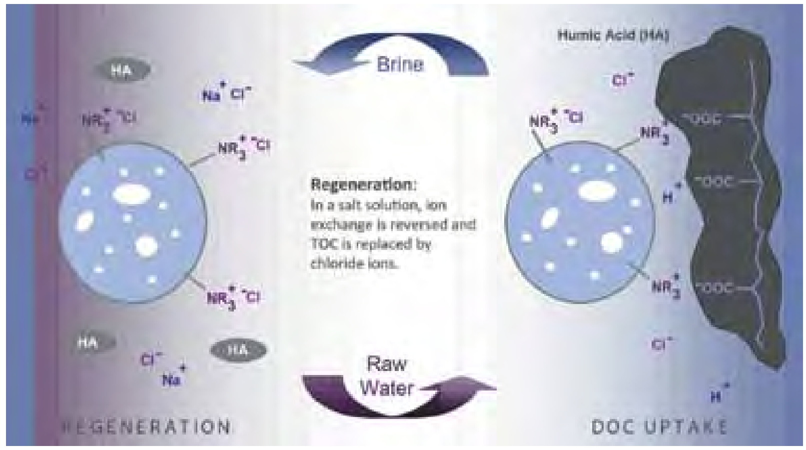
BOTTOM: The worker on the ground and those on the walkway above give perspective on the size of the pipes that crisscross the water plant.

Design Honor Award

H. Clay "Junk" Whaley, Sr. Memorial Water Plant

St. Cloud, Florida

ENTRANT: Jones Edmunds & Associates, Inc.
ENGINEER-IN-CHARGE: Thomas W. Friedrich, P.E., BCEE



LEFT: The design of the facility incorporated low-profile design of process structures and equipment, an advanced security system with detection fence and dark night concept to save power costs and minimize impacts of bright facility lights on the surrounding community.

RIGHT: The MIEX® resin has properties that allowed Jones Edmunds to design a unique solution. The resin is very small (180 micron), magnetic, macroporous, anionic, acrylic resin that is used in continuous mixed process. The resin removes hydrogen sulfide (bisulfide form) in addition to DOC and color.

After years of complaints from the its residents, St. Cloud began seeking a long-term solution to improve drinking water quality and, at the same time, design a facility that was energy efficient to operate and blended with the surrounding community. Following the investigation of treatment alternatives, MIEX® was determined to be the best solution.

Jones Edmunds & Associates, Inc. created the largest operating magnetic ion-exchange (MIEX®) water plant in the United States. The facility lowered TTHMs and HAAs below the MCL and provided EPA-compliant water within three days of coming online on March 27, 2008.

Jones Edmunds designed the MIEX® plant to prevent the formation of disinfection byproducts in the City's potable water to achieve compliance with EPA's Stage I DBP Rule. It also reduced chlorine demand by 90%, removed 61% of DOC, an eliminated 98% of odor, reduced total sulfide to below 0.3 mg/L, and removed color to below the MCL of 5 color units.

Design Honor Award

Heart of the Valley Metropolitan Sewerage District Wastewater Treatment Facility Improvements

Kaukauna, Wisconsin

Entrant: McMahon

Engineer-in-Charge: Thomas J. Kispert, P.E., BCEE

The Heart of the Valley Metropolitan Sewerage District (HOVMSD), along with their Neenah-based engineering consultant, McMahon, developed a unique combination of treatment systems to upgrade the 35-million gallon per day Wastewater Treatment Facility, located in Kaukauna. The HOVMSD provides wastewater treatment services to the City of Kaukauna, Villages of Little Chute, Kimberly and Combined Locks, and the Darboy Sanitary District.

The Wastewater Treatment Facility, originally constructed in the 1930's, was expanded to a 6.5 mgd regional facility in the late 1970's. In 2003, HOVMSD retained McMahon and initiated Facilities Planning to address several needs, including continued rapid growth in the service area, persistent peak wet weather flows, and the need to meet a new discharge permit limit for ammonia nitrogen.

The HOVSMD facility is the first installation in the U.S. that couples ballasted sedimentation and BAF systems for treatment of municipal wastewater. The facility has been successfully operating since completion in 2008.

TOP: Biostyr Influent Piping. Biostyr flows are distributed across eight individual cells. Dedicated blowers and automatic actuators allow each cell to backwash independently.

BOTTOM: HOVSMD New Site Plan. The triangular-shaped site is bounded by the Fox River canal on the north and Thilmany Paper Mill on the south and west. Expanding the plant required creative, high rate processes and significant coordination to keep the existing plant operational during construction.

Design Honor Award

City of Clovis Sewage Treatment/Water Reuse Facility

Clovis, California

ENTRANT: CH2M Hill
ENGINEER-IN-CHARGE: Steven C. Patterson, P.E.

The City of Clovis was interested in building a city-owned Sewage Treatment and Water Reuse Facility in the Southeast area of Clovis, California. CH2M Hill was hired to design, construct, operate, and maintain the facility for 10 years, and assist in obtaining permits and government approvals for the new facility. CH2M Hill was chose, in part, because of its innovative design that features a small plant footprint.

The primary goal was to design a facility to treat 2.8 mgds with the potential for expansion to 8.4. The project would also include the design and construction of a pump station to service the ST/WRF and the upgrade of a separate pump station to also service the new ST/WRF.

The wastewater treatment/water reuse facility will relieve the demand on underground and surface water supplies, provide recycled water for irrigation, will use less energy, and is incredibly neighbor and environmentally friendly.

TOP: A view from the headworks shows the bioreactor in the foreground, the membrane equipment building and emergency generator housing in the midground, and the recycled water storage tank in the background.

BOTTOM: The City of Clovis Sewage Treatment and Water Reuse Facility will use state-of-the-art technology to support future development in the northwest and southeast outer reaches and northeast urban centers of the community near Fresno, California.

University Research Honor Award

Improved Water Quality in Northwest Tanzania

Shirati, Tanzania

ENTRANT: University of Cincinnati Department of Civil and Environmental Engineering
ENGINEER-IN-CHARGE: Daniel B. Oerther, Ph.D., P.E., BCEE

University of Cincinnati Professor Dr. Daniel B. Oerther has been teaming with the Village Life Outreach Project to bring safe drinking water to twenty thousand villagers in Northwestern Tanzania.

Dr. Oerther has visited East Africa seven times in the past three years partnered with students, faculty, and staff of the University as well as volunteers of Village Life. He developed a multi-tiered approach including source water protection, drinking water treatment, and safe water storage. Drinking water treatment technologies focused on a multi-barrier approach including coagulation, filtration, and solar disinfection. Collectively, these technologies provide a level of public health protection similar to conventional drinking water treatment employed in developed countries.

Currently, more than three hundred slow sand drinking water filters have been constructed, coagulation with seed pod extracts from *Moringa oleifera* (an indigenous tree) is underway, and solar disinfection utilizing PET bottles purchased by Village Life locally.

TOP: Villager Tom Mboya posing with a slow sand filter he constructed at his uncle's home near Shirati, Tanzania.

BOTTOM: Villagers in Burere, Tanzania, use solar disinfection to treat water from Lake Victoria in PET bottles collected from the Village Life team from the USA.

Small Projects Honor Award

Seneca Lake State Park Sprayground
Geneva, New York

ENTRANT: Malcolm Pirnie, Inc.
ENGINEER-IN-CHARGE: Daniel J. Loewenstein, P.E., BCEE

In summer 2005, a *Cryptosporidium* outbreak resulted in approximately 4,000 cases of reported illnesses in 37 different counties in New York State. The NYS DOH linked the outbreak to the Seneca Lake State Park Sprayground, a recreational facility for young children, owned and operated by the New York State Office of Parks, Recreation and Historic Preservation, and containing 32 above and below-ground water features that shoot, spray and/or gush water.

Malcolm Pirnie performed a detailed facility evaluation to determine the outbreak's potential cause; assessed the system's capability to protect the public from *Cryptosporidium* and other pathogens; evaluated options to reduce the risk of future outbreaks; and planned, permitted, designed and constructed Sprayground improvements.

The innovative treatment system they designed — UV irradiation combined with partial filtration of recirculated water — was one of the first UV reactors constructed to meet the regulations that would subsequently be promulgated, and the only reactor to be validated on site.

TOP: With the new treatment facilities in operation, the public can now feel confident in the safety of their children enjoying the Sprayground.

BOTTOM: The solution designed by the engineers utilizes innovative UV irradiation technology, provided by low-pressure, high-output reactors that deliver effective dosages at lower transmissivitives to account for sunscreens washed off by patrons. This was the first application of its kind for spraygrounds.

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Volume 8, Spring 2009

Environmental Engineer: Applied Research and Practice

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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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REVIEW PROCESS

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.

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.

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MODULAR NITROGEN REMOVAL IN DISTRIBUTED SANITATION WATER TREATMENT SYSTEMS

Daniel P. Smith, Ph.D., P.E., DEE[1]

ABSTRACT

Removal of nitrogen from onsite sanitation water was demonstrated using three experimental two-stage biofiltration systems treating septic tank effluent (STE). Each system consisted of a vertical flow unsaturated trickle filter followed by a horizontal saturated denitrification filter with elemental sulfur as electron donor. Unsaturated filter media were clinoptilolite, expanded clay, and recycled granular rubber. The sole mechanical component of each filter was a single liquid pump that provided pressure dosing at a 30 min. interval and a hydraulic loading rate of 3 gallons per square foot per day (gal/ft^2-day) (0.12 m/day). The systems were operated for over eight months on STE with an average total nitrogen (TN) concentration of 72.2 milligrams per liter (mg/L). The two-stage filters employing clinoptilolite, expanded clay and granular rubber media produced average final effluent TN of 2.2, 2.6 and 27 mg/L, respectively, with average TN removal efficiencies of 97, 96 and 65%. Dissolved organic nitrogen was the predominant form of nitrogen in treated effluent. Reduction of carbonaceous biochemical oxygen demand (CBOD) exceeded 94% for all three systems. The results demonstrated that the two-stage biofiltration design using a single pump was highly effective in reducing nitrogen in onsite sanitation water, and produced an effluent of comparable quality to centralized wastewater systems that employ external carbon dosing for tertiary denitrification.

INTRODUCTION

Domestic sanitation water from over one-fifth of U.S. households is treated in individual or small community cluster systems (U.S. Census Bureau, 2008). This material differs from typical municipal domestic wastewater in that it is typically more concentrated. Population growth, exurban development trends, and the cost and energy of centralized conveyance and treatment make it likely that distributed infrastructure will continue to be used for the management of a large portion of domestic sanitation water in the U.S. The importance of distributed or decentralized wastewater systems was recognized by the U.S. Environmental Protection Agency (EPA) in its 1997 Report to Congress stating that "adequately managed decentralized wastewater systems are a cost-effective and long-term option for meeting public health and water quality goals, particularly in less densely populated areas" (US EPA, 1997).

The most common system for onsite sanitation water treatment and subsurface discharge has been the ***septic system***, which consists of a ***septic tank*** followed by application to soil in drainfield (aka ***leachfield or subsurface wastewater infiltration system (SWIS)*** (US EPA, 2002a, 2002b). The ***septic tank*** receives household effluent and provides separation by sedimentation and flotation, hydrolysis of particulate and colloidal components, and anaerobic digestion. In conventional systems, septic tank effluent (STE) is distributed under the soil surface into an unsaturated porous layer of natural soil. STE trickles through the unsaturated media, which acts as a biological filter. The filter provides for capture and degradation of particulates and colloids, aerobic oxidation of organics, nitrification, and retention of virus and pathogenic bacteria. Nitrogen removal in conventional treatment systems is quite limited, with removal efficiencies of less than 5% in the ***septic tank*** and 10 to 20% in ***drainfields*** (Water Environment Research Foundation, 2008; Costa et al., 2002; US EPA, 2002a). Recent analyses have applied rational engineering concepts and newer terminology. Thus, the ***septic tank*** can be termed ***primary treatment***, due to its functional similarity to primary sedimentation in centralized wastewater treatment (Water Environment Research Foundation, 2008). ***Soil treatment unit*** (STU) is used to designate an in-situ soil system that is designed using rational and scientific analyses of treatment capacity, as opposed to the simple effluent dispersal function connoted by ***drainfield*** (Siegrist, 2006).

Total nitrogen (TN) in septic tank effluent typically ranges from 40 to 75 mg/L, and nitrogen levels may increase with future water conservation (IWA, 2001; US EPA, 2002a). A variety of treatment systems have been developed to increase nitrogen reduction over that provided by conventional onsite treatment (i.e. a primary treatment tank followed by soil application). These systems employ biological treatment as additional unit operations located after or integrated with the septic tank. Many are proprietary products which have undergone testing according to protocols developed by NSF International.

Systems for nitrogen reduction enhancement can be classified by a number of factors. The most prominent are the use of suspended growth or fixed film biological reactors, unsaturated aerobic trickle filters, and recycling of nitrified effluent to increase total nitrogen removal by pre-denitrification. Treatment components can be integrated with primary treatment or can treat STE separately. Examples of the former are multi-chamber tanks with separate compartments for primary treatment and aerated suspended growth followed by recycle, use of an external aerated tank with recycle, and systems that pump STE to a trickle filter that discharges nitrified effluent back into the primary treatment tank. In these examples, sanitation water organics provide electron donor for pre-denitrification. A variety of fixed film processes enhance nitrogen reduction by nitrification and simultaneous nitrification/denitrification, in single pass mode and recirculation mode with pre-denitrification. Prominent fixed film media include sand, peat, foam, and synthetic textiles (Smith et al., 2008). These systems typically reduce Total nitrogen in STE by 30 to 75%, leaving 10 to 20 mg/L TN or greater in the effluent (Smith et al., 2008; US EPA, 2002a; Anderson et al., 1998).

Onsite systems that employ multiple liquid pumps, aerators, or mixers are considered more "active" systems and would ostensibly require greater energy, operation and maintenance costs. More "passive" treatment systems with a small number of mechanical and electrical components may be more appropriate for individual onsite sanitation water systems. In particular, fixed film biofiltration appears to most suitably fill the specific requirements for onsite treatment systems at individual residences: resilient and reliable treatment, low operator attention, low maintenance, and low energy consumption.

APPROACH TO PASSIVE NITROGEN REMOVAL

It was desired to demonstrate a relatively passive nitrogen removal system suitable for onsite sanitation water. A primary consideration was to evaluate systems with limited reliance on pumping, no forced aeration, and that were resilient and required low maintenance and operator attention. An overall approach to passive nitrogen removal was conceived as an integrated two-stage biological filter system (Smith et al., 2008). The first stage is an unsaturated aerobic vertical flow filter, intermittently dosed at the upper surface, to attain ammonification and nitrification. The second stage is a saturated anoxic filter containing reactive media that serves as an electron donor for denitrification. This configuration was mandated by the obligatory biochemical sequence of aerobic nitrification followed by anoxic denitrification. The use of an unsaturated media filter for the initial aerobic stage is necessary because of the constraint that aeration pumps would not be used. The first media filter can be established as a downflow filter connected to an anoxic denitrification filter that operates in an upflow, horizontal or downflow mode. Flow connectivity between the two filter stages would be by gravity.

The experimental investigation was designed to simulate one general configuration of contained two-stage biofiltration for treating STE to prepare it for soil dispersal: a vertical unsaturated flow filter followed by a horizontal saturated flow filter. This contained in-tank process provides access to filter media for maintenance and replacement and the ability to positively sample and monitor effluents. Supplementation or replacement of denitrification media could be accomplished without disturbing the first stage media. This process configuration avoids the uncertainties associated with reliance on natural subsurface flow systems for treatment. The Stage 2 filter could be deployed as a horizontal filter bed located partially or fully in the subsurface provided it remained saturated and all Stage 1 filter effluent was obligated to pass through it.

Stage 1 Filter

The design goal established for the unsaturated Stage 1 filter was based on the final effluent ammonium N. The TN in the final effluent of the two-stage biofilter would consist of organic nitrogen, ammonia, and oxidized nitrogen (nitrate and nitrite). The presence of each nitrogen form in final effluent would contribute to lower reduction efficiency. Since ammonium would be largely conservative or could possibly increase through the Stage 2 anoxic filter, the Stage 1 effluent ammonia level was established as less than 1 mg/L. Review of onsite filter technologies suggests that it is possible to achieve ammonium nitrogen reductions of 95% and effluent ammonium N levels of 1 mg/L (Smith et al., 2008). Unsaturated filters that are operated on STE can also provide some denitrification through simultaneous nitrification and denitrification. Though denitrification is desirable, however, the predominant design goal of the first stage filter was to achieve low levels of ammonium N. Such a process would be presumed to also provide high conversions of organic nitrogen and high reductions in carbonaceous biochemical oxygen demand (CBOD).

Unsaturated filter performance is governed by the manner in which septic tank effluent is imposed on the media surface and the characteristics of the filter media. Key design factors are the average applied hydraulic and organic loading rates, the timing and volume of STE dosings, and dosing distribution across the entire surface area of the filter. Significant media factors are media type, particle size, the ability to retain water, and maintenance of aeration pore volume for oxygen transfer to biofilm surfaces. The capture and biodegradation of particulate and colloidal solids and heterotrophic oxidation of organics will occur in the first stage filter media, and adequate pore space must be provided to avoid clogging, particularly at and near the upper filter surface. Evaluation of specific filter media, hydraulic and organic loading rates, and water quality was needed to define the design parameters needed to achieve low effluent ammonium and organic N concentrations. Promising candidate media included zeolites, expanded clays and shales, tire crumb, peat, coconut coir, and synthetic fiber materials. The first stage unsaturated filter should also produce an effluent with low total suspended solids (TSS) and heterotrophic regrowth potential to minimize potential solids accumulation and channeling in the second stage filter.

Stage 2 Filter

The Stage 2 filter receives predominantly nitrate and must reduce total oxidized nitrogen (TON) to low concentrations in the final effluent. Stage 2 filter design considerations include the electron donor media, media surface area per volume for electron donor dissolution and microbial growth, the propensity for accumulated suspended solids to reduce hydraulic conductivity and create preferential flow, and design factors such as applied hydraulic and organic loading rates. Central to the denitrification filter function is the need to provide a continuous supply of electron donor for denitrification over extended periods of deployment. A literature review was conducted to identify candidate electron donor media for denitrification (Smith et al., 2008). Two prominent cost effective materials were identified: elemental sulfur for autotrophic denitrification (Sengupta and Ergas, 2006; Zeng and Zhang, 2004; Darbi et al., 2003) and lignocellulosic materials including woodchips and sawdust for heterotrophic denitrification (Kim et al., 2003; Schipper and Vojvodic-Vukovic, 2001; Robertson et al., 2000). The literature review suggested that effluent nitrate nitrogen levels of less than 2 mg/L are achievable.

Two additional considerations regarding anoxic reactive media must be addressed. The first is residuals that are added to water by passage through the reactive media. Wood based materials add biodegradable organics to water, increasing biochemical oxygen demand (CBOD), while elemental sulfur systems would release sulfate and possibly sulfide. The degree to which residuals are of concern is related to their concentrations, the time duration of elevated concentration, and the ultimate receiving waters. Anoxic filter designs must supply sufficient electron donor for denitrification over a specified length of time, but with as small a release of by products as is feasible. Sulfur-based biofilter designs could perhaps be developed with low effluent by-product levels or combined with other electron donor materials in hybrid denitrification filters.

In addition to serving as an electron donor, the anoxic filter media must provide extended hydraulic and reactive performance. Preferential flow paths can be initiated through deposition of organic and inorganic solids within the filter media, and by the methods used to distribute water into and withdraw water from the reactive media. Channelization, reduced contact with reactive media surfaces, and performance deterioration can result. The ability to predict a priori the propensity for channelization phenomena is limited, particularly for the biochemically reactive anoxic filter environments that feature complex water chemistry and a significant entrance zone redox transition from aerobic to anoxic. Approaches to overcoming channelization include inlet and outlet arrangements, manipulation of media, the provision of adequate head to overcome headloss buildup, baffling, biofilter aspect ratio, use of large systems that provide acceptable performance over time even with some degree of channelization, or smaller filters with lower retention times and more frequent media replacement. Continuous deployment of treatment systems over periods of months and longer are needed to fully examine these factors.

MATERIALS AND METHODS

A schematic of the experimental filter is shown in Figure 1. Three two-stage filter systems (denoted as A, B, and C respectively) were evaluated, each consisting of an unsaturated filter followed by a saturated filter. The Stage 1 filters were vertically oriented and Stage 2

FIGURE 1 Experimental Filter System Schematic

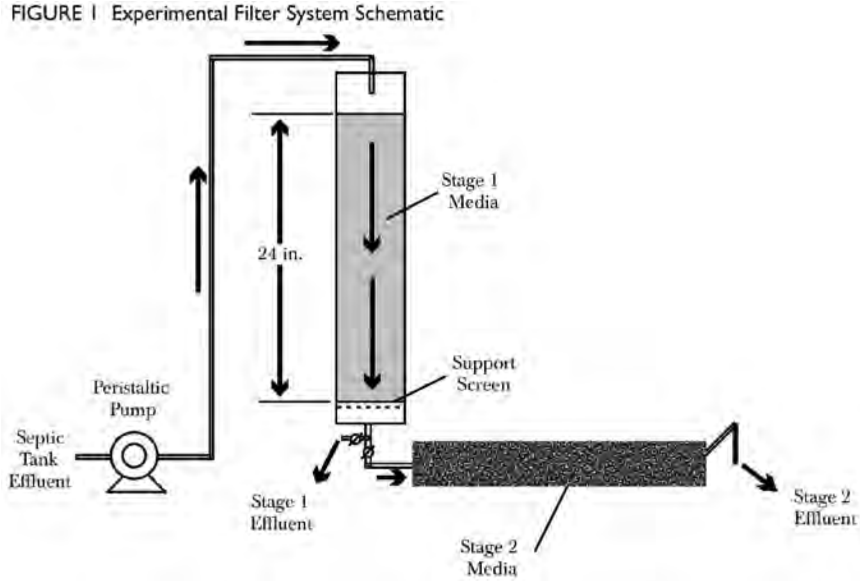


TABLE 1 Filter Media

Filter	Media	Features
Stage 1 Filter Unsaturated Nitrification	Zeo-Pure AMZ Clinoptilolite	High water retention Cation exchange
	Livlite Expanded Clay	High water retention
	Granular Rubber	Recycled material
Stage 2 Filter Saturated Denitrification	Elemental sulfur	Autotrophic electron donor
	Oyster shell	Alkalinity source
	ACT-MX ESF-450 Utelite	Anion exchange

TABLE 2 Two-Stage Filter Media Configuration

Stage	Filter	Column inner diameter, inch	Media layer thickness, inch	Media placement	Media			
Stage 1 unsaturated aerobic	A1	3.0	24.0	Stratified	Clinoptilolite	depth (in.) 8 8 6 1 1	diameter (mm) 2.38 - 4.76 1.19 - 2.38 0.5 - 1.19 1.19 - 2.38 2.38 - 4.76	top ↓ bottom
	B1				Expanded Clay	depth (in.) 8 8 6 1 1	diameter (mm) 2.38 - 4.76 1.19 - 2.38 0.5 - 1.19 1.19 - 2.38 2.38 - 4.76	top ↓ bottom
	C1				Granular Rubber	depth (in.) 8 8 6 1 1	diameter (mm) 2.38 - 4.76 1.19 - 2.38 0.5 - 1.19 1.19 - 2.38 2.38 - 4.76	top ↓ bottom
Stage 2 saturated anoxic	A2	1.5	24.0	Nonstratified (1-3 mm)	75% elemental sulfur 25% oyster shell			
	B2				60% elemental sulfur 20% oyster shell 20% expanded shale			
	C2				45% elemental sulfur 15% oyster shell 40% expanded shale			

filters oriented horizontally (Figure 1). Stage 1 (unsaturated) filters were fabricated from 3 inch (76 mm) inner diameter columns and 1.5 inch (38 mm) inner diameter columns were used for Stage 2 (saturated) filters. A 1/8 inch (3.2 mm) square mesh screen was used for media support and retention at the outlet end of each filter. The filter media that were evaluated are listed in Table 1, and the media used in each stage of Systems A, B, and C are shown in Table 2. Stage 1 media included clinoptilolite, expanded clay and tire crumb, all of which provide substantial external porosity (> 45%). Clinoptilolite and expanded clay would be expected to exhibit higher water retention water characteristics when compared to granular rubber. Additionally, clinoptilolite provides 1.5 to 1.8 milliequivalents per gram (meq/g) cationic exchange capacity which could enhance sorption and retention of ammonium ions. Granular rubber is produced by the shredding and cutting of recycled tires, and is available in particle sizes of 5 mm and less that are suitable for use as filter media.

The Stage 2 electron donor media was elemental sulfur, which provided an autotrophic denitrification process in the anoxic filter. Autotrophic denitrification with elemental sulfur can be represented with the following biochemical reaction:

$$50\ S^0 + 49.9\ NO_3^{-} + 11\ CO_2 + 32.8\ H_2O \rightarrow 2.2\ C_5H_7O_2N + 50\ SO_4^{-2} + 23.8\ N_2 + 50.1\ H^+$$

According to this stoichiometry, 50.1 equivalents of alkalinity are consumed per 49.9 mole nitrate, or 3.59 gram alkalinity as $CaCO_3$ per gram of NO_3^--N. Complete denitrification of 50 mg/L nitrate nitrogen in the influent by a sulfur based denitrification filter would require an alkalinity of 179.5 mg/l as $CaCO_3$. As sulfur-based autotrophic denitrification will consume alkalinity, crushed oyster shell was used as an alkalinity source. Expanded shale was included in the Stage 2 filters of Systems A and B and provided anion exchange capacity, which would sorb nitrate under non-steady operational conditions.

A single peristaltic pump (Cole Parmer L/S7523-60) was used to dose septic tank effluent to the three two-stage filters with a separate pump head for each system. STE was withdrawn from the septic tank through a 3 in. diameter cylindrical intake manifold containing 1/16 in. slots to strain large particles as is standard current STE withdrawal practice. Pump head size, peristaltic tubing, and pump speed and run time were identical for all three Two-Stage Filter systems.

The media configuration in the six filters is shown in Table 2. Total media depth in the vertical unsaturated Stage 1 filters was 24 in. The Stage 1 filters employed a stratified media configuration, with larger particle sizes at the top and decreasing size in the downward direction. Larger size particles were used in the bottom 2 in. for particle retention. Particle size stratification in the unsaturated filters was based on the expected progression of physical and biochemical processes within the filter media. Larger particle sizes were used in the upper media layer to provide larger internal spaces where the greatest accumulation of organic and inorganic mass will occur. Processes in the surface layer of Stage 1 media are most intense, including adsorption of particulates and colloids, hydrolysis and release of soluble organics, aerobic utilization of soluble organics, and biomass synthesis. In this region, biochemical processing of organic matter between doses must keep pace with the newly applied constituents from each STE dose. Smaller particle sizes at greater depths in the filter provide greater surface area for water retention, nitrification, and pathogen retention. Stratified media should enhance the potential for long term operation while maintaining treatment efficiency.

Three Stage 2 filters were constructed using unstratified media containing elemental sulfur, crushed oyster shell, and expanded shale of 24 in. total media depth (Table 2). Each filter contained a 3:1 vol./vol. ratio of elemental sulfur to crushed oyster shell. The fraction of expanded shale in Stage 2 media ranged from 0 to 40%. Expanded shale contains anion exchange capacity which can bind nitrate ions, potentially enhancing removal. Higher expanded shale fractions were accompanied by lower elemental sulfur fractions, which would reduce the total surface area of elemental sulfur and possibly the overall sulfur oxidation rate. A lower sulfur oxidation rates could have the effect of reducing effluent sulfate levels if sulfur oxidation exceeded the stoichiometric denitrification requirement.

The Stage 1 filters received an STE dose once per every thirty minutes (48 doses/day). Water trickled downward through the Stage 1 media, through the support screen, and into a connecting pipe that directed Stage 1 effluent to the Stage 2 filter (Figure 1). The water elevation in the tube below the Stage 1 filter provided hydraulic head for passive movement of water through the Stage 2 filter. A valve and sample port (with another valve) was located in the tube below the Stage 1 filter. In normal filter operation, the sample port valve was closed and the valve leading to Stage 2 open, providing passive flow of Stage 1 effluent to and through the horizontal Stage 2 filter. The design of the two-stage filter system minimized internal volume within the connecting piping; liquid volumes in the Stage 1 and Stage 2 filters comprised greater than 90% of the total internal volume.

The experimental studies were conducted at Flatwoods Park, a day use public recreational facility in Hillsborough County, Florida. Sanitation water at the site is generated by two sources: a continuously occupied single family home used as a ranger residence and a day use lavatory with two flush toilets and two hand washing sinks. Sanitation water from the two sources is collected in a septic tank and pumped to a mound system for infiltration. STE from the septic tank was used in this study. The park was open for public use every day throughout the study, which was conducted from 1/2/2008 to 9/4/2008. The source water provided to the ranger residence and lavatory facility was municipal drinking water from the City of Tampa.

Monitoring was conducted at seven monitoring points: septic tank effluent (STE), three Stage 1 filter effluents, and three Stage 2 filter effluents. Temperature, pH, dissolved oxygen (DO) and oxidation reduction potential (ORP) measurements were performed by inserting probes directly into Stage 1 effluent collection reservoirs and Stage 2 effluent ports, and for STE into a 1 liter sample container immediately after collection. Effluents of Stage 1 and Stage 2 filters were collected for nitrogen and sulfate analyses by routing the effluent flow over a four to six hour period directly into prepared sample containers located in iced coolers. STE samples for sulfate, nitrogen, biochemical oxygen demand (BOD), and total suspended solids (TSS) analyses were collected by directly filling prepared sample containers with STE pumped from the septic tank over a one to two minute period and immediately placing

TABLE 3 Applied Hydraulic Loading Rate

System	Media	Average (gal/ft^2-day)	Standard Deviation (gal/ft^2-day)
A	Clinoptilolite/75% Sulfur	2.77	0.24
B	Expanded clay/60% Sulfur	2.93	0.32
C	Tire crumb/45% Sulfur	2.69	0.36

n = 31

TABLE 4 Septic Tank Effluent Quality

Component	Average	Standard Deviation	Range	n
Total Nitrogen	72.2	15.6	50 - 98	10
Organic Nitrogen	8.2	3.6	3 - 14	9
NH_3-N	63.4	17.0	41 - 91	8
NO_x-N	0.06	0.07	.025 - .25	9
DO	0.02	0.01	0 - .03	10
ORP	-385	8.8	-375 - -395	5
pH	7.43	0.31	7.11 - 7.99	10
Alkalinity	471	122	140 - 569	10

(all values in mg/L except pH)

TABLE 5 Nitrogen Species in Filter Influents and Effluents

Sample Point	Total Nitrogen	Organic N	NH_3-N	NO_x-N	Total Inorganic Nitrogen
Influent (STE)	72.2	8.2	63.4	0.065	63.5
Stage 1 Effluent					
A Clinoptilolite	43.6	1.1	0.036	38.8	41.0
B Expanded clay	59.7	1.0	0.13	58.9	59.0
C Granular rubber	66.6	3.5	15.4	47.7	63.1
Stage 2 Effluent					
A 75% Sulfur	2.2	1.8	0.30	0.03	0.34
B 60% Sulfur	2.6	1.7	0.9	0.03	0.96
C 45% Sulfur	27.1	3.0	19.8	4.3	24.1

Days 1 to 245; Average of n=10; all values in mg/L sample containers on ice in a cooler.

Nitrogen and C-BOD_5 analyses were performed by a National Environmental Laboratory Accreditation Conference (NELAC) certified laboratory (ELAB Inc.). Total Kjeldahl nitrogen (TKN) was performed by digestion and colorimetric determination (EPA 351.2). Ammonium nitrogen was performed by semi-automated colorimetry (EPA 350.1). Nitrate plus nitrite nitrogen analysis was performed by cadmium reduction and colorimetry (EPA 353.2). Sulfate was measured by anion chromatography (EPA 300.0). Quality assurance and control procedures were followed by ELAB Inc. Temperature, pH and dissolved oxygen (DO) were measured using a Hach 40d multimeter with Intellical glass membrane probe and luminescent Dissolved Oxygen probe. Probes were calibrated according to manufacturer's instructions using three standard solutions (4,7,10) for pH, and an air saturated water solution and a zero DO (sodium sulfide) solution for DO. The Hach LDO probe (LDO 10103) included a temperature sensor that performed automatic temperature compensation for DO. ORP was measured using a Hanna HI991003 pH/ORP/Temperature meter. Total alkalinity was measured by titration with 1.6N sulfuric acid to a bromocresol green-methyl red endpoint.

TABLE 6 Nitrogen Removal Efficiency of Two-Stage Biofiltration

System	Media	Total Nitrogen Reduction %		Total Inorganic Nitrogen Reduction %	
		Average	Range	Average	Range
A	Clinoptilolite/75% S	97.0	94.9 - 97.9	99.5	98.6 - 99.9
B	Expanded Clay/60% S	96.2	93.7 - 98.6	97.6	96.0 - 98.7
C	Granular Rubber/45% S	64.6	2.2 - 93.6	68.3	2.1 - 98.9

Days 1 to 245; Average of n=10

FIGURE 2 Total Nitrogen in STE and Two-Stage Biofilter Effluents

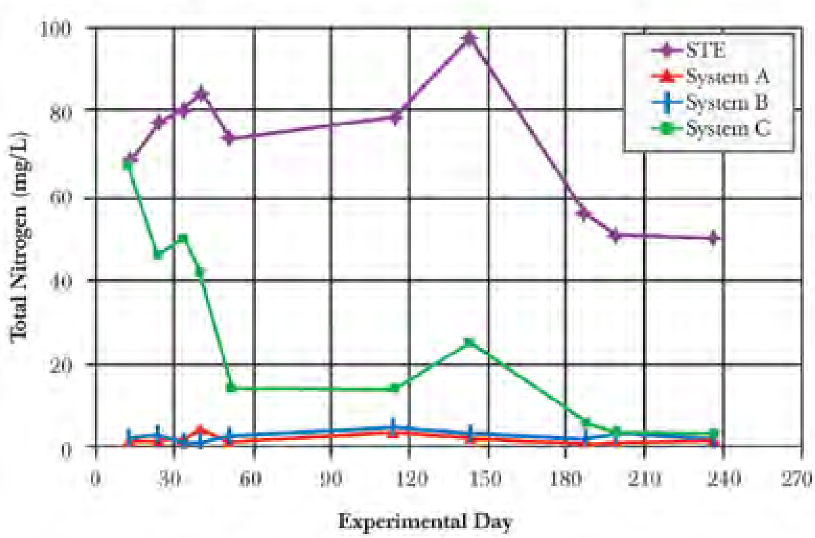
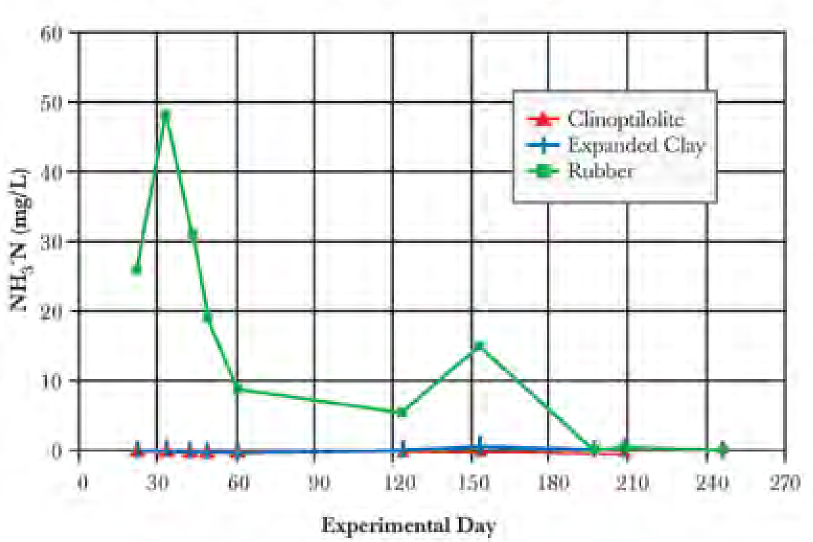


FIGURE 3 Effluent Ammonia Nitrogen from Unsaturated (Stage 1) Filters



RESULTS AND DISCUSSION

Applied hydraulic loadings to Stage 1 filters are summarized in Table 3. Flowrates were measured by collecting and quantifying the cumulative liquid volume exiting the Stage 2 filters (i.e. the final effluent) over time periods of 15 to 40 hours and dividing by elapsed time. Flowrates were fairly consistent and average hydraulic loadings were within 10% of the target rate to Stage 1 filters (3 gal/ft^2-day).

Septic tank water quality parameters are summarized in Table 4. The average total nitrogen (TN) of 77.2 mg/L was somewhat higher than typical for single family residences and may reflect the contribution of day use flow to the mixed sanitation water. The majority of STE nitrogen was TKN and was dominated by ammonium, as is a common STE characteristic. STE ORP reflected low values characteristic of anaerobic environments.

Nitrogen species are summarized in Table 5 for each of the two-stage systems. Nitrogen removal efficiencies are summarized in Table 6. Total nitrogen concentrations of the two-stage filter systems are presented in Figure 2. Average TN removal efficiencies of Systems A (clinoptilolite) and B (expanded clay) were 96.8 and 95.1%, respectively, with average effluent TN of 2.2 and 2.6 mg/L. The excellent performance of the biofilter systems with clinoptilolite and expanded clay Stage 1 media was not matched by System C (granular rubber). Average System C effluent TN was significantly higher than Systems A and B, prior to Day 210 (Figure 2) due to both lower ammonium removal in the filter C1 and lower nitrate removal in filter C2.

Ammonium nitrogen levels in effluent from the unsaturated Stage 1 filters are shown in Figure 3. Ammonium nitrogen reductions in the clinoptilolite and expanded clay filters averaged 97% or greater with effluent often less than 0.1 mg/L. High ammonia removal for these systems was established within the first month of operation and continued for over eight months. Ammonia remained significantly higher in the effluent of the System C Stage 1 filter (granular rubber) and reached relatively low levels only after six months (Figure 3). The reason that the granular rubber media filter exhibited a long acclimation time for nitrification is unknown.

The performance of the three denitrification (Stage 2) filters is illustrated in Figure 4. Throughout the study, NOx concentrations were quite low (Figure 4) and TIN removal efficiencies were high (Table 6) for System A (clinoptilolite/75% sulfur) and System B (expanded clay/60% sulfur). System C (granular rubber/ 40% sulfur) showed less complete NO_x removal through Day 210. Total nitrogen removal efficiency of the two-stage filters reflects the removal efficiency of both ammonia and nitrate (Figure 5). The System A and System B filters, with clinoptilolite and expanded clay respectively, provided 94% TN removal consistently over the eight month period. A comparable removal efficiency in System C (granular rubber media) required over 5 months of operation (Figure 5).

Removal of five day carbonaceous biochemical oxygen demand (C-BOD_5) in Stage 1 filters was evaluated in three sampling events. C-BOD_5 ranged from 120 to 160 mg/L in STE and from < 2 to < 8 in the effluents of all three Stage 1 biofilters (Table 7). The designations of "less than" in the reported results are due to the different dilutions that were applied in the BOD test bottles for the sampling events. For all three Stage 1 filters, the removal efficiency of C-BOD_5 ranged from > 94 to > 98%. The results verified the expectation that an efficiently nitrifying biofilter would be accompanied by a high reduction in organic oxygen demand.

Field monitoring parameters are summarized in Table 8. Each of the

FIGURE 4 NO_x Concentrations in Stage 2 Biofilter Effluents

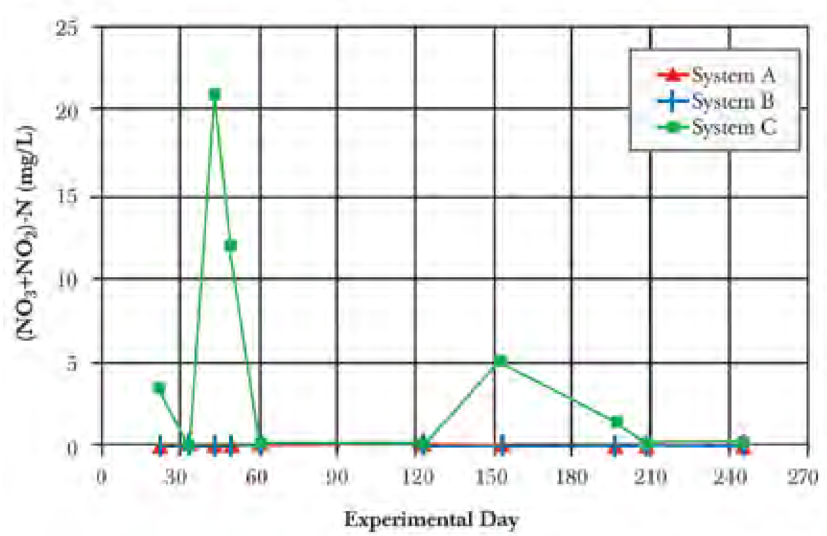


FIGURE 5 Total Nitrogen Removal Efficiencies of Two-Stage Filters

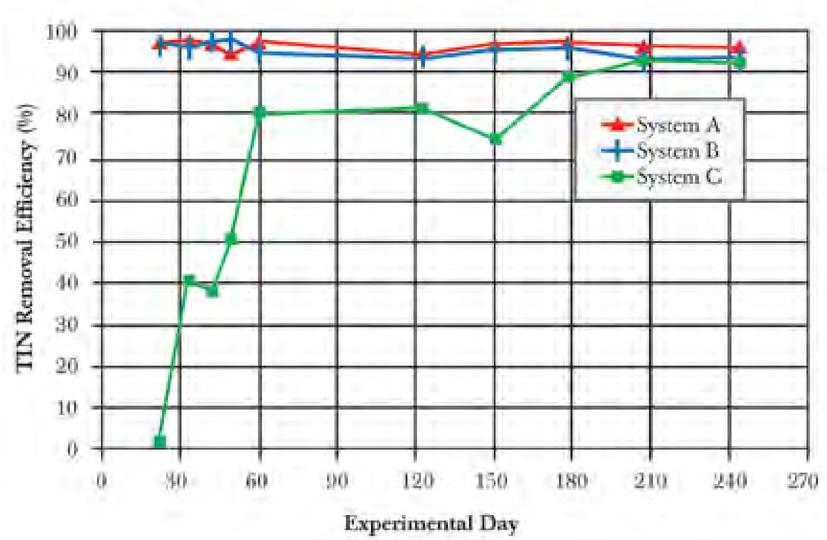


TABLE 7 Carbonaceous Biochemical Oxygen Demand in STE and Stage I Effluents

Date	Effluent C-BOD_5, mg/L			
	Septic Tank	Clinoptilolite	Expanded Clay	Granular Rubber
5/4/2008	130	< 8	< 8	< 8
6/3/2008	160	4.0	3.5	8.4
7/2/2008	120	< 2	< 2	< 2
% Removal Efficiency	-	>94,98,>98	>94,98,>98	>94,95,>98

TABLE 8 Average Field Parameter Values for Days 1 to 245

Sample Point	Dissolved Oxygen, mg/L	ORP, mV	pH	Alkalinity, mg/L as $CaCO_3$	Alkalinity Change, mg/L as $CaCO_3$
Influent (STE)	0.02	-385	7.42	471	-
Stage 1 Effluent					
A Clinoptilolite	7.13	74	7.33	224	-248
B Expanded clay	7.01	93	6.81	71	-401
C Granular rubber	6.17	85	6.90	118	-353
Stage 2 Effluent					
A 75% Sulfur	0.06	-362	6.90	404	+180
B 60% Sulfur	0.06	-348	6.82	245	+174
C 45% Sulfur	0.53	-212	6.90	250	+132
n=10					

FIGURE 6 Dissolved Oxygen in Effluent of Denitrification Biofilters (Stage 2)

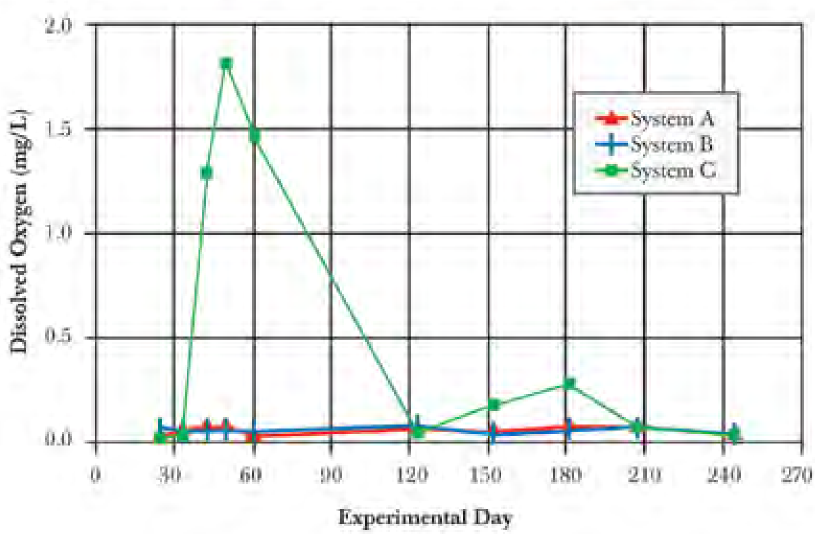
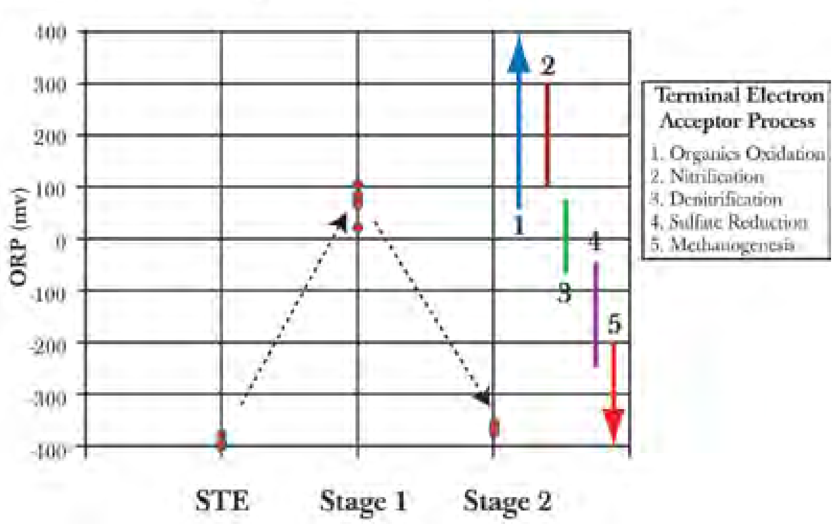


FIGURE 7 ORP Profile through Two-Stage Biofilter System A (Clinoptilolite/75% Sulfur)



three Stage 1 media was effective in increasing dissolved oxygen (DO) from virtually zero in STE to typically 6 mg/l or greater. DO was in turn significantly decreased by passage through the saturated Stage 2 filters (Figure 6). Effluent DO was consistently less than 0.5 mg/L in the final effluents of Systems A and B but not consistently low in the final effluent of System C. The pH of Stage 1 effluents were lower than that of STE but remained in a circumneutral range (Table 8). Alkalinity also declined significantly through the Stage 1 filters as was expected based on the consumption of 4.57 mg/l alkalinity as $CaCO_3$ per gram ammonia nitrogen nitrified according to biochemical stoichiometry. Conversely, alkalinity increased through the Stage 2 filters, indicating that the supply of alkalinity by oyster shell was more than sufficient to offset alkalinity destruction by sulfur based autotrophic denitrification.

The profiles of oxidation reduction potential (ORP) through the System A biofilters are shown in Figure 7 along with ORP ranges associated with biochemical oxidation of organics, nitrification, denitrification, sulfate reduction and methanogenesis (Wei et al., 2009; Holman and Wareham, 2003; Stumm and Morgan, 1996). ORP was in the methanogenic region in STE and was increased significantly by passage through the unsaturated filter. The ORP of clinoptilolite filter effluent was 20 to 110 mV and poised in the region which spans biochemical processes expected to be operative within unsaturated trickle filters treating STE: organics oxidation, nitrification and denitrification. Passage through the anoxic denitrification filter reduced ORP to less than 350 mV, in the methanogenic range in which denitrification can readily occur.

At the conclusion of the study, the media at the top surface of Stage 1 filters was visually observed and photographed. For all three Stage 1 media, the general shapes of the particles at the filter surfaces were clearly discernable and appeared similar to fresh media. Eight months of continuous operation resulted in only minor visually observable accumulations of deposits and reductions in pore openings. Stage 1 media that were removed from the up-

FIGURE 8 Stage 1 Media, Upper Layer Dried at 103°C (Day 246)

Left to right: System A: clinoptilolite; System B: expanded; System C: granular rubber

FIGURE 9 Filter 2A, 21 in. (Day 246)

FIGURE 10 Filter 2A, 2 in. (Day 246)

per media surface of the Stage 1 filters at the conclusion of the study and dried at 103°C are shown in Figure 8.

Photographs of the System A, Stage 2 media at the termination of the study are shown in Figures 9 and 10. A cutaway section of Filter A2 at 21 in. from the entrance is shown in Figure 9. There was no observable material accumulation on the media or within the filter at that location. For all three Stage 2 filters, sulfur from the filter midpoint to the effluent end appeared similar to new, unused sulfur media.

In contrast, materials accumulation was observed on media from the entrance region of all three Stage 2 filters. The entrance region of a Stage 2 filter is a biologically unstable zone in which oxygenated and nitrified Stage 1 effluent is contacted with elemental sulfur electron donor. As such, a region of active microbial processes and biomass accumulation should result. In Figure 10 is shown the appearance of media from the entrance region of Filter A2 before drying. Media nearer the filter entrance (right hand side in Figure 10) were coated with a a gelatinous material, which was less pronounced on media farther from the filter entrance (i.e. to left in Figure 10). A similar coating was also observed on entrance region media from the other Stage 2 filters. The gelatinous coating was taken as evidence of active microbial activity in the Stage 2 entrance regions, presumably associated with dissolution and oxidation of elemental sulfur with oxygen and nitrate in the Stage 1 filter effluents acting as electron acceptors. The gelatenous coating was much less observable after drying at 103°C, although entrance region clinoptilolite and expanded clay retained a darker appearance than fresh media.

SUMMARY AND CONCLUSIONS

Two-stage biofiltration treating septic tank effluent reduced total nitrogen by over 95% over an eight month period and produced effluent total nitrogen concentrations of less than 2.5 mg/L. Biofilter systems consisted of a vertical flow unsaturated trickle filter for aerobic treatment followed by horizontal saturated denitrification filters with elemental sulfur as electron donor. Systems were of relatively passive design, with a single effluent dosing pump as sole mechanical component and energy requirement. Nitrogen and carbonaceous BOD levels produced by two-stage biofiltration were comparable to the effluents of centralized treatment plants employing external carbon dosing for tertiary nitrogen removal (US EPA, 1993). Nitrogen speciation in biofilter effluent was also similar to large treatment plants, and consisted predominantly of dissolved organic nitrogen. Total inorganic nitrogen was typically less than 0.5 mg/L and often at or below analytical detection limits.

Two-stage filters employing clinoptilolite and expanded clay media provided exceptional performance within three weeks of startup. These media appear to be highly suitable for passive two-stage biofiltration. The granular rubber filter, however, required an extended acclimation time for nitrification, suggesting that this media should be used with caution. The exceptional ammonia removal with clinoptilolite and expanded clay at 3 gal./ft^2-day suggests that higher loading rates could provide acceptable performance. Pilot and full scale verifications would be needed before the advantages of smaller filter size and reduced cost could be realized.

Denitrification filters employing elemental sulfur for autotrophic denitrification performed extremely well when treating the effluents of clinoptilolite and expanded clay filters. Although this study operated denitrification filters successfully for over eight months, performance over longer time periods remains an open question. The apparent accumulation of biomass in the filter entrance zone could ultimately lead to hydraulic failure. The high level of biological activity in the entrance region could also have contributed to substantial nitrate reduction within a short length into the denitrification filters. Further studies with denitrification filters of different loading rates and aspect ratios, with nitrate profile measurements, would assist in addressing these questions. Alkalinity change through Stage 2 filters suggest that a lower portion of alkalinity supplying material could be used in the media mix. Longer term operation of denitrification filters is needed to address these issues and develop basic guidance for design.

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