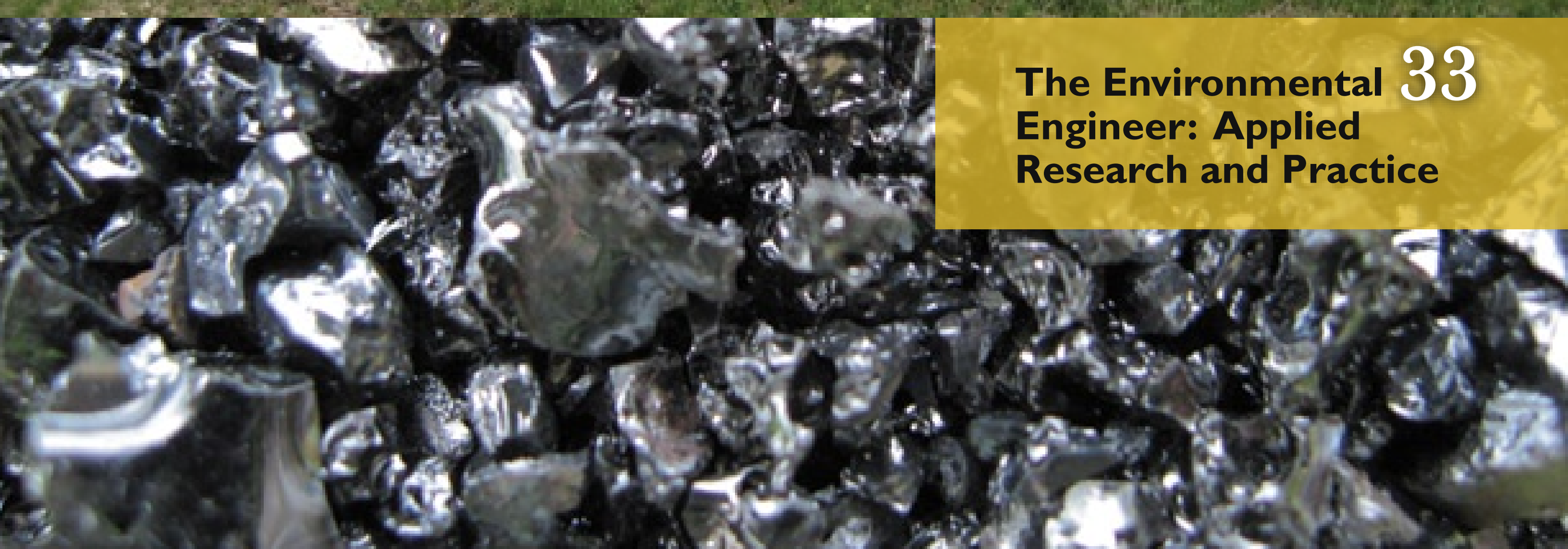
THE MAGAZINE OF THE AMERICAN ACADEMY OF ENVIRONMENTAL ENGINEERS®

ENVIRONMENTAL ENGINEER

VOLUME 43 NUMBER 2 — SPRING 2007



The American Academy of Environmental Engineers WorldPoints® Credit Card
Rewards you can really get into.

A check for $250. A flight across the country or anywhere in the world. A big-screen TV. If you can dream it, the new American Academy of Environmental Engineers Platinum Plus® MasterCard® credit card with WorldPoints® rewards can make it happen.

We couldn't be more proud to offer you this exciting new credit card rewards program at competitive rates. Issued by MBNA, the leader in affinity credit cards, it's got everything you'd want in a card and much more, all with NO ANNUAL FEE. *

Rich Rewards. You'll earn one point for every net retail dollar you spend with your card toward:

- Unlimited cash rewards
- Tickets on major U.S. airlines with no blackout dates
- Car rentals and hotel stays in the U.S.
- Brand-name merchandise
- Plus, double, triple and quadruple points can be earned at participating merchants, and redemption can begin with as few as 2,500 points.

World-Class Service. MyConcierge℠ service, a complimentary cardholder service, offers you the advantage of a personal assistant that can help you:

- Find tickets to sold-out shows and sporting events
- Locate a special gift
- Even help plan a function for you

Exceptional Benefits. Because you'll want to use your WorldPoints card for everything—shopping, recurring bills, dining out, gas, and emergencies—you'll have access to a powerful credit line as high as $100,000 and equally impressive coverage to protect you and your purchases.

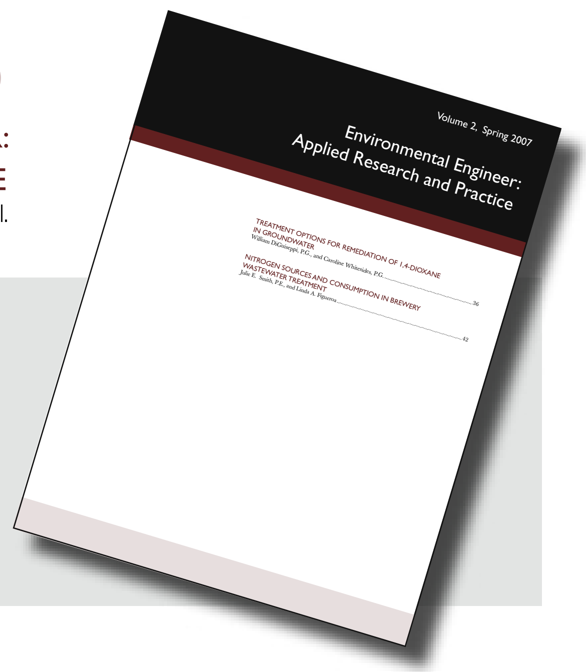
What's more, the card that rewards you supports our organization. Each time you make a purchase with your credit card, a contribution is made to the American Academy of Environmental Engineers at no additional cost to you.

Learn more—call toll-free 1-866-438-6262 (TTY users, call 1-800-833-6262). Please refer to priority code MCUA when speaking with an MBNA representative to apply.

*For information about the rates, fees, other costs, and benefits associated with the use of the card; or to apply, please call the above toll-free numbers.

MBNA, WorldPoints, the WorldPoints design, the tree symbol, and the MBNA logo are service marks of MBNA America Bank, N.A. MasterCard is a federally registered service mark of MasterCard International, Inc. and is used by MBNA pursuant to license.

ENVIRONMENTAL ENGINEER


Volume 2, Spring 2007
Environmental Engineer: Applied Research and Practice
TREATMENT OPTIONS FOR REMEDIATION OF 1,4-DIOXANE IN GROUNDWATER
William DiGuiseppi, P.G., and Caroline Whitesides, P.G. 36
NITROGEN SOURCES AND CONSUMPTION IN BREWERY WASTEWATER TREATMENT
Julie E. Smith, P.E., and Linda A. Figueroa 42

Cover photo courtesy of Donohue & Associates, Inc., Superior Achievement Award Winner for the 2007 E3 Competition.

BY STEPHEN R. KELLOGG, P.E., BCEE

FUNDING THE PLAN

THE AMERICAN ACADEMY OF ENVIRONMENTAL ENGINEERS IS A VOLUNTEER ORGANIZATION. It's success is dependent upon the time donated by individuals that believe in the Academy and its principles. I am grateful to the many individuals that serve on, or chair committees, those that host regional meetings, and the many that pass the word and help in the recruitment of new members. As we all move on in our careers, it is important to "prime" the pipeline with a new supply of younger members.

The demographics of the Academy are such that we will be losing many members to retirement at perhaps the same rate as new members are recruited. This makes it difficult to accomplish the many objectives that we have as an environmental engineering organization. While we have held our own over the last several years, your Board of Trustees has determined that the time has come for a bold course of action. That course is the implementation of our new Strategic Plan for growth.

At our upcoming Board of Trustees meeting in May, we will be discussing the plan and its final details, as well as participating in a half day work shop on plan implementation issues. Many Strategic Plans are well thought out, but fail as a result of implementation. Your Board is committed to ensuring that we guide the plan over its five year course by assigning roles and responsibilities that go beyond the terms of Officers in the Academy. It must be a longer-term document than the one-year term served by the President and other officers.

As I mentioned in my last message "Moving Forward", a key component of the plan involves reaching into our universities and learning institutions to connect to students and professors producing tomorrow's environmental engineers. We envision a strategy of connecting with younger engineers earlier in the process to provide a smooth transition from student to board certified professional. Our student member category is part of this strategy. We are also welcoming the many qualified teaching professionals in our teaching institutions into AAEE, even though some may not have chosen to become registered. We recognize that outside of the consulting phase of our profession many highly qualified professionals may not have been encouraged to seek registration, yet in many cases their professional experience warrants consideration for membership in the Academy.

All of this activity will take time, resources and an investment. In the recent AAEE on-line member survey seeking your opinions on priorities, over 150 of you indicated that you would be willing to volunteer to help the Academy in many areas. These include identifying articles for *Environmental Engineer* magazine, recruiting members, hosting local meetings, proctoring exams, developing seminars, and serving as liaisons to local colleges and universities to promote AAEE to students and faculty. A key area where I personally need assistance is in the implementation of our campaign to provide the funding over the next five years to implement our new strategic plan.

The objective is to raise at least $150,000 to fund the five-year effort. We are looking for a commitment of $1,000 over three years payable as a note to the Academy for $333 per year. While modest, we believe it will provide the resources to assist in jump starting our growth drive. I ask each of you who can to make this commitment. If you can't participate at that level, please do what you can. As you know from my last communication, the Board of Trustees have seeded this fund with a $15,000 commitment.

Consulting membership has been the cornerstone of the Academy's membership since its inception. I am looking for leaders from consulting firms to volunteer as "campaign managers" and take the lead on personally contacting key employees to seek their commitment to the program. I would like to see participation from our major utilities and seek leaders from each to do the same. While our membership numbers are less in academia, I would ask for a volunteer from each of those institutions with board certified members. Lastly, I ask that any of you from industry, regulatory and other agencies to volunteer for this effort. All who are willing to assist should contact AAEE headquarters and let us know that you're ready to help.

I have been a member of AAEE for twenty years. I have served as a Trustee-at-Large, Vice-President, National Membership Chair, and State Representative. I have had the pleasure of studying under two of the Academy's Past Presidents and working directly for two more. AAEE leadership have assisted me in my career from the beginning. I owe the Academy and that in part is why I want to ensure that when I leave office on December 31, 2007, AAEE has the resources in place to implement our plan for growth and expanded service for the environmental engineering profession. That can only happen with help from our membership through volunteering. Our success has been and always will be dependent on the efforts of volunteers. Please indicate your willingness to participate by contributing what you can via the note program and assisting me to make the campaign a success. Our future depends on it. A

ENVIRONMENTAL ENGINEER

The Quarterly Magazine of The American Academy of Environmental Engineers®

www.aaee.net

Editorial Staff
C. Robert Baillod, Ph.D.
Editor-in-Chief, Applied Research & Practice

Editor
Yolanda Y. Moulden, News, Currents, and Careers

Art & Graphics
Susan C. Zarriello

Production
Yolanda Y. Moulden

Advertising
Yolanda Y. Moulden, General Sales
J. Sammi Olmo, Professional Cards
410-266-3311 • FAX 410-266-7653
e-mail: info@aaee.net

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

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

AAEE RECOGNIZES FOUR AWARD HONOREES

At the Annual AAEE Award Luncheon on May 2 at the National Press Club in Washington, D.C., four Honorees were recognized for their contributions to the Academy and the Environmental Engineering Profession.

MATTHEW DOMINY, P.E., BCEE was presented with the Stanley E. Kappe Award. Those receiving the Kappe award have performed extraordinary and outstanding service contributory to significant advancement of public awareness to the betterment of the total environment and other objectives of the Academy.

JAMES F. STAHL, P.E., BCEE received the Gordon Maskew Fair Award. The Fair Award is given annually to those recognized as having contributed substantially to the status of the environmental engineering profession and to the Academy by: exemplary professional conduct, recognized engineering achievements and significant contributions to the control of the quality of the world's environment.

LEO WEAVER, P.E., BCEE was the recipient of the Edward J. Cleary Award. The Cleary award is given to an individual who is an outstanding performer in the management of environmental protection enterprises conducted under either public or private auspices who have demonstrated exemplary professional conduct, personal leadership, originality in devising new environmental protection techniques and sensitivity and responsiveness to social, economic and political factors in environmental protection.

DANIEL J. GUNARATNAM, PH.D., P.E., BCEE has been named Honorary Board Certified Environmental Engineer. One Honorary Board Certified Environmental Engineer may be selected each year by the Academy's Board of Trustees by affirmative vote of at least two-thirds of its members. The individual so honored has attained a position of eminence in the environmental engineering profession; has made a singular noteworthy contribution, or a sustained contribution, to the advancement of environmental engineering; and has performed outstanding service over a relatively long period of time in the advancement of the affairs of the Academy.

Full profiles of this year's Honorees can be found on pages 14 through 17.

APPLICATIONS FOR 2007 ARE CLOSED

The application period for BCEE/BCM for 2007 closed on March 31st. AAEE received 105 applications by the deadline, up from last year.

The AAEE office will begin scheduling exams in May. The exam period will run through September, and the successful exam candidates will be reviewed and certified by the Board at it's Annual Meeting this coming November.

'UPGRADING' *ENVIRONMENTAL ENGINEER*

As many have noticed, the previous edition of *Environmental Engineer* (Winter 2007, Volume 43, Number 1) featured the premiere of *Environmental Engineer: Applied Research and Practice*. The journal section of *Environmental Engineer* features peer-reviewed, technical papers. Early indications are that this is a welcome, and long-overdue, addition.

The Editorial Board, headed by Editor and Chair, C. Robert Baillod, Ph.D., P.E., BCEE, encourages authors of such papers that are focused on practical research and useful case studies related to environmental engineering to submit their papers for consideration for publication in future editions of the journal. See page 35 for contribution information.

BY LAWRENCE A. PENCAK

YOUR CHANCE TO SWEEP A DOUBLE HEADER

Please consider submitting to the 2008 competition and showcasing your accomplishments.

IT IS NOT OFTEN THAT TWO AWARDS CAN BE WON WITH JUST ONE ENTRY, but that prospect is now a possible outcome for the 2007 and 2008 winners of the AAEE's Excellence in Environmental Engineering (E3) Competition. Since its debut in 1989, the E3 Competition has recognized the best in contemporary environmental engineering. New technologies and innovative designs are showcased, and the winners are acknowledged as national trendsetters and accomplished problem solvers.

Last year in this publication the introductory lead-in to the article introducing the 2006 competition award winners stated, "They are a small percentage of the many projects involving environmental engineers around the world." They are indeed a small percentage of the total on the world stage, but once on that stage they become a large percentage of the best in the world in environmental engineering. The London-based International Water Association worldwide 2006 Awards Competition named five E3 Competition awardees as award winners amongst their eighteen winners. The E3's Grand Prize in Research winner was also IWA's Global Grand Prize winner in the Applied Research category (*Environmental Engineer*, Vol. 43, No. 1-Winter 2007; pgs. 5, 11, 12).

IWA's Project Innovation Awards honor excellence and innovation in water engineering projects around the world. Awards are presented in the categories of Applied Research, Planning, Design, Operations/Management, and Small Projects. The next IWA Project Innovation Awards will be presented in 2008 in Vienna. The top two winners in each category of the Academy's Excellence in Environmental Engineering Competition in both 2007 and 2008 are automatically eligible to enter the IWA's analogous award's category. Judging by the results of the 2006 IWA competition, the AAEE winners are very competitive and well positioned to win… again.

If you missed the 2007 E3 Competition you still have a chance in 2008 to debut on the world stage, and entering the AAEE's competition is now easier with an all-electronic submission format. The new format was introduced this year and in a follow-up survey of submitters all but one found the new format simple, straightforward, and overall easier than the previous process. Please consider submitting to the 2008 competition and showcasing your accomplishments. You'll have a real opportunity to be the winning pitcher of two games, and one is 'televised' worldwide. A

MEMBER NEWS

TAPAS K. DAS, PH.D., P.E., BCEE, has been named Chair of AIChE's *Environmental Division.* Dr. Das has been certified in Air Pollution Control since 2002.

TERRY KRAUSE, P.E., BCEE, has been named Vice President and Senior Program Manager at CH2M Hill. Mr. Krause has been certified in Water Supply & Wastewater Engineering since 2005.

LOUIS A. RAIMONDI, P.E., L.S., BCEE, was presented with the New Jersey Institute of Technology (NJIT) Alumni Achievement Award. Mr. Raimondi is NCEES President and Senior Project Manager for Maser Consulting (West Nyack, NY). He has been certified in Water Supply & Wastewater Engineering since 1989.

IN MEMORIAM

DONALD A.B. MILLS, P.E., BCEE, passed away in August 2006. Mr. Mills served as the AAEE State Representative of Alabama. He was an Engineer at Goodwyn, Mills & Cawood, Inc., and had been certified in Sanitary Engineering since 1977.

LETTERS TO THE EDITOR

I read with interest the article "Challenges to Implementing Drinking Water Technologies in Developing World Countries" published in *Environmental Engineer* (Winter 2007, Vol. 43 No. 1).

It was good to see the Academy again highlighting the importance of safe drinking water in developing countries through this article. Congratulations to the authors for their well planned and implemented study and their clear and concise article.

Among the conclusions of the study, the authors found that past failures for implementing water purification technology in developing countries have primarily been due to lack of training and maintenance. Having worked in this field exclusively in developing countries for the past 19-years, my experience tells me that very often a more fundamental factor underlying such failures is weak, unenforced or non-existent government policies and regulations on systems' operations and maintenance and supporting programs such as operator training and certification.

Countries have got to get the policy and institutional framework right before they can hope to achieve safe and sustainable community water supply systems on a large scale. Too many water suppliers - public and private - fail to make the necessary investments in training and maintenance when there are neither incentives for doing so nor disincentives for failing to do so.

Terrence Thompson, P.E, BCEE, F. ASCE
Philippines

OFFICER NOMINEES FOR 2008

The Academy's Nominating Committee is chaired by Alan H. Vicory, Jr.. It's members include Timothy G. Shea, Jeanette Brown, Robert P. Gardner, Neal E. Armstrong, and Jeffrey H. Greenfield. The committee recommends the following slate of candidates:

President Elect	Debra R. Reinhart
Vice President	Cecil Lue-Hing
	Brian P. Flynn
Trustee-at-Large	Rao Y. Surampalli
	C. Robert Baillod
	LeRoy C. Feusner
	Gary S. Logsdon

PRESIDENT-ELECT

DR. DEBBIE REINHART has been a member of the University of Central Florida faculty since 1989. In 1996 she became the Associate Dean for Research for the College of Engineering and Computer Science. From 2003-2005 she served as the interim Chair of Civil and Environmental Engineering. During the past eighteen years, she has been teaching and conducting research in the solid and hazardous waste fields. Dr. Reinhart received her B.S. in Environmental Engineering from UCF and M.S. and Ph.D. degrees in Environmental Engineering from the Georgia Institute of Technology. She is a registered professional engineer in Florida and Georgia, a Board Certified Environmental Engineer of the American Academy of Environmental Engineers, and a Fellow of ASCE. Dr. Reinhart has authored four books and over 100 journal and proceeding articles. She holds five patents.

Debbie has served on the boards of two national organizations (American Academy of Environmental Engineers and the Association of Environmental Engineering and Science Professors); a national research foundation (the Environmental Research and Education Foundation); and one state organization (Florida section of the Air and Waste Management Association). She has also chaired two national American Society of Civil Engineer committees (Solid Waste and External Organization Coordinating Committees). Debbie has served as a reviewer for more than 25 journals and organizations. She has been on the editorial board for three archival journals.

Debbie has been an active member of AAEE. She has been a member of the Board of Trustees for a total of eight years, three as the ASCE Trustee and five as the AEESP Trustee. She currently holds the office of Vice President and has been on the Executive Committee for two years. She served as the chair of the American Academy of Environmental Engineers Diversity Task Force. She currently serves on the Recertification Committee, the Planning Committee, and the Member and Student Member Working Groups. She is chairing the Body of Knowledge Working Group. In addition she is an ABET Environmental Engineering Program Evaluator.

VICE PRESIDENT

CECIL LUE-HING is the former Director of Research and Development of the Metropolitan Water Reclamation District of Greater Chicago (District), a position he occupied between 1971 and 1999. He currently operates as a private practitioner environmental consultant as President of Cecil Lue-Hing, and Associates Inc., a sole proprietorship Chicago-based Illinois Corporation. Prior to Chicago, he was a Vice President of Ryckman, Edgerley, Tomlinson and Associates, an environmental consulting firm in St. Louis, Missouri. Cecil has earned degrees from Marquette, Case Western Reserve, and Washington University in St. Louis, in Civil, and Environmental & Sanitary Engineering. His career in private practice, government, and applied research has given him the opportunity to experience and appreciate the varied interests and challenges of the profession.

Cecil has made many notable contributions to wastewater technology including two patents, by his scores of publications in the professional journals, eight books on a wide range of subjects in environmental engineering/science, and has given freely of his time to the cause of professional development through volunteer service to AAEE- Board of Trustees, Chair Eminence and Planning Committees; ASCE- Past President EWRI, Past Chair Environmental Engineering EXCOM; WEF- Past Chair Board of Editorial Review; IWA- Past Secretary Treasurer of USANC; AMSA-Past President, Past Chair Biosolids Management Committee; and USEPA- former member SAB Environmental Engineering Committee. His awards include AAEE-Kappe Lecturer 2003, G.Maskew Fair Award 2001; ASCE-Natl. Govt. Civil Engineer of the Year 1996, Simon Freese Award and Lecturer 1992; WEF-Chas. Emerson Medal 1996, and AMSA- Environmental Award 1999 and 1998, President's Award 1992.

Cecil is an Honorary Member of ASCE, was certified a Diplomate by the Academy in 1982, and was elected a Member of the National Academy of Engineering in 2000.

As Vice President of AAEE, Cecil will be committed to strengthening the Academy's position as the nation's premier certifying body for Environmental Engineers while extending its influence to better embrace and keep pace with the changing culture, demographics, and engineering/science demands of the profession.

BRIAN P. FLYNN is an environmental/chemical engineer with 37 years of environmental engineering and business experience. He operates a unique international bi-functional consulting practice in these two areas. He holds 3 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 on the Board of Trustees, is the Chair of the Planning Committee (which is developing a 5 year strategic plan), and is past Chair of the Membership Committee. He has also developed a Financial Management course for the Academy, is serving as Board liaison to the hazardous waste exam committee, 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.

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 29 years. He is currently a member of the Board of Directors of ERM-New England.

During Mr. Flynn's 37 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 on 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.

TRUSTEE-AT-LARGE

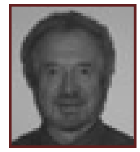
RAO Y. SURAMPALLI received his M.S and Ph.D. degrees in Environmental Engineering from Oklahoma State and Iowa State Universities. He is a Registered Professional Engineer in the branches of Civil and Environmental Engineering, and is an Engineer Director with United States Environmental Protection Agency (USEPA) and has been with EPA for the past 21 years. His career in private practice, government, university and applied research has given him the opportunity to experience and appreciate the varied interests and challenges of the environmental engineering profession.

He has authored more than 370 technical publications, including five (5) books, 31 book chapters, 136 refereed journal articles, presented at 180 national and international conferences, and given over 30 plenary, keynote or invited presentations worldwide. He serves on 39 national and international committees, review panels, or advisory boards including the ASCE National Energy, Environmental and Water Resources Policy Committee. He is Editor of ASCE Hazardous, Toxic, and Radioactive Waste Management Journal and serves on the Editorial Board of WEF Water Environment Research Journal. He also serves on the Editorial Boards of three other refereed Environmental Journals. He is an Adjunct Professor of Environmental Engineering at five universities: Iowa State University-Ames, University of Missouri-Columbia, University of Nebraska-Lincoln, University of Quebec-Sainte Foy and University of Missouri-Rolla.

He has provided technical assistance, facilitated technology transfer, and built technical capacity for numerous developed and developing nations including Brazil, India, Nepal, Taiwan, Japan, Thailand, Panama, Kazakhstan, Namibia, Philippines and Korea.

His awards include ASCE National Government Civil Engineer of the Year 2006 and the Best Practice Oriented Paper Award 2001, NSPE National Federal Engineer of the Year and Founders Gold Medal 2001, NSPE Top Ten Federal Engineers of the Year 2000 and 2001, WEF Philip Morgan Award 1986, EPA's Scientific and Technological Achievement Award 1993, EPA Engineer of the Year (1987, 2000, and 2001), USPHS Outstanding Service Medal (1995 and 2001) and the Samuel Lin Award 1999, and the American Society of Military Engineer's (ASME) Hollis Medal 2000.

Rao is a Distinguished Engineering Alumnus of both the Oklahoma State University (2001) and Iowa State University (2002), and was elected a Fellow of the American Association for the Advancement of Science (AAAS) in 2005. Rao also is a Fellow of ASCE and was certified a Diplomate by the Academy in 1985.



C. ROBERT "BOB" BAILLOD is professor Civil and Environmental Engineering at Michigan Tech. He is a licensed professional engineer in Michigan, and has been a Diplomate of AAEE since 1987.

Bob's service to AAEE includes: Membership Committee, Affiliates Committee, Chair of the Engineering Education Committee, and Chair of the Fourth AAEE/AEESP Education Conference. He currently serves on the Environmental Engineering Body of Knowledge Task Force, chairs the Publications Committee, and is the Editor of the new Applied Research and Practice Section of The Environmental Engineer. He is a Program Evaluator for the Accreditation Board for Engineering and Technology (ABET) for environmental engineering and for civil engineering and is the AAEE Alternate to the ABET Board of Directors. He is a past member of the Michigan Transportation Commission and chairs the Portage Lake Water and Sewage Authority.

He received his baccalaureate degree in civil engineering from Marquette University and earned his masters and doctoral degrees from the University of Wisconsin. He has served on the Michigan Tech faculty since 1968, and has had sabbatical appointments as a guest professor at the University of Wisconsin, Rogaland University in Stavanger, Norway, and the University of Sonora in Hermosillo, Mexico. He was elected to the Board of Directors of the Association of Environmental Engineering and Science Professors (AEESP) and served as Vice President and President of AEESP from 1990-92.

Bob has taught a variety of civil/environmental engineering subjects, and specializes in wastewater engineering and treatment. His research emphasizes the design and operation of biological wastewater treatment plants with emphasis on oxygen transfer and aeration. He has authored fifty publications related to wastewater treatment, oxygen transfer, residuals reuse, and environmental engineering education, and has directed forty-five graduate research reports, theses and dissertations. He is a co-recipient of the American Foundrymen's Society Best Paper Award and the Michigan Society of Professional Engineers Outstanding Achievement in Education Award.

Baillod is a Fellow and Life Member of ASCE, and a Life member of the Water Environment Federation (WEF). He serves on the ASCE Oxygen Transfer Standards Committee and has served on the WEF Program Committee and has chaired the WEF Research Symposium Subcommittee.

LEROY C. FEUSNER is a chemical/environmental engineer with 39 years of environmental engineering experience. He received his B.S. in Chemical Engineering from the University of Wyoming in 1968. After graduation, he was commissioned into the Air Force as a Bioenvironmental Engineer. He earned several military decorations, including USAFR Outstanding Bioenvironmental Engineer during his Operation Desert Storm deployment in 1991.

Since 1978, he has worked for the Wyoming Department of Environmental Quality, Water Quality Division, as a district office engineering supevisor (1978 to 1986); environmental quality emergency response supervisor (1986 to 1990); Storage Tank Program Engineering Supervisor (1990 to 2006).

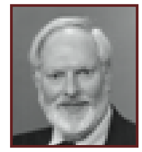
In March 2006, Mr. Feusner was appointed to the position of Administrator, Solid and Hazardous Waste Division, within the department. This new professional opportunity presents tremendous state-wide management and technical challenges in assisting local governments in evaluating groundwater pollution from over 65 statewide solid waste landfills and implementing an environmental remediation program that may be partially financed by the state to contain and remediate pollution from these landfills. Additionally, he manages a comprehensive hazardous waste program that includes a voluntary remediation program, orphan sites, and abandoned waste facilities while continuing to be responsible for the state storage tank program.

Mr. Feusner is a licensed professional engineer in South Dakota and Wyoming. He worked with NCEES in the early 1990s to define environmental engineer and establish the professional knowledges for the national environmental engineering license examination. He is also a member of the American Institute of Chemical Engineers, the National Groundwater Association, and the Wyoming Citizens Action Group which was formed to make recommendations for investigating and cleaning up the state's solid waste landfills. Additionally, he has considered it a personal and professional honor to have received the first Academy certification in the hazardous waste management specialty in 1987.

Since becoming a Diplomate in 1984, he has served as Chair of the Hazardous Waste Sub-Committee, Chair of the Examination Committee, Wyoming Academy Membership Chair, and the Academy representative on the Participating Organizations Liaison Council of the National Council of Examiners for Engineering and Surveying. Mr. Feusner completed a three year Academy commitment on the Re-Certification Committee and a three year term as Chair of that Committee. Mr. Feusner has also been active and supportive of the recent Academy's Bylaws, Policies, and Procedures Committee work to discuss, evaluate, and implement modified membership criteria and processes for the continued membership growth of the Academy. This input has involved information concerning the Diplomate re-certification process and procedures, along with constructive comments on committee work.

His many years of professional environmental engineering work experience and his continual involvement in Academy committee work activities are strong indicators of his dedication and support for the Academy's mission and future.

He and his wife, Lynnette, a successful Creative Memories Scrapbook Business Director, have been married for 39 years with two grown daughters. Mr. Feusner is also active in several community youth activities sponsored locally by the Cheyenne Kiwanis Club.



GARY S. LOGSDON received his B.S.C.E. and M.S. San. E. from the University of Missouri (Columbia) and D.Sc. in Environmental Engineering (1971) from Washington University (St. Louis).

He served as a Commissioned Officer with the U. S. Public Health Service for 26 years. Much of his career focused on drinking water research and water filtration. He retired in 1989 and began a second career with Black & Veatch, directing pilot plant filtration studies and evaluating water filtration plants. He retired from Black & Veatch in 2004 and now is a self-employed consultant.

Past American Water Works Association activities include member, Coagulation & Filtration Committee; Chair, Filter Materials Standards Committee; Chair, Small Systems Guidance Committee; Chair, Small Systems Policy Committee; and member; Technical & Professional Council. He is on the Michigan Section AWWA's Research & Technical Practices Committee. Logsdon served on two National Research Council committees and one term on the Water Science & Technology Board. He has been an Associate Editor for the Journal of Environmental Engineering & Science since 2001.

Professional honors include member, Civil Engineering Academy of Distinguished Alumni, University of Missouri; and the A. P. Black Research Award from AWWA.

He is a Licensed Professional Engineer in Michigan and was certified as an Academy Diplomate in 1984. Logsdon has served one term as an Academy Trustee, was a member and subsequently Chair of the Water Supply and Wastewater Subcommittee, and was the 2004 Kappe Lecturer, making 16 official Kappe visits at colleges and universities. A

MARKETING: NO PLAN, NO PROFIT:

If You Can Manage Your Projects, You Can Manage Your Marketing

by Brian P. Flynn, P.E., BCEE

Well, almost. Sure, you can probably make a profit without a marketing plan. But, if you are armed with a plan, you will make more profit and grow faster. A growth environment is always more fun to be in.

ATTITUDES

If a politician wants to do some good, they have to be elected first. Unfortunately, this is also true in the world of Environmental Engineering: If you want to do some good for your client, you have to be selected.

I vividly remember my first experience at selling something. Chocolate candy bars for my elementary school. Cowering in dank apartment building hallways, going door to door, selling to friends, neighbors, and (mostly) strangers. Getting doors closed in my face. Sometimes, I think that most young engineers look at marketing with the same emotional baggage. It doesn't have to be that way.

Rather, it should be looked upon as an interesting exercise in getting to know someone else's environmental problems or opportunities well enough to see the outlines of a solution. It is in an engaging discussion that is an intellectual challenge and a problem solving exercise. Just the kind of thing that engineers excel at.

DEFINITIONS

A prospect is someone whom I would *like* to have as a client. A client is someone who buys my services. Marketing is the attempt to define a prospect's or client's needs and match them with my services. Once I have done this, sales is the process (usually a proposal) by which I turn the concept into a contract for an engagement.

PLAN CONTENTS

Many of my consulting firm clients have told me that "of course we have a marketing plan". All too often, they have the elements of a plan, but not the whole thing. ***See the insert for a typical outline of a complete marketing plan. (page 13)***

It is very hard to grow faster than the marketplace. If you service your existing clients and do not market, you will probably shrink 10 to 20% per year, due to natural loss of clients, i.e they do not stay with you forever. If you market within your comfort zone (existing practice areas and market segments) without a comprehensive plan, you will grow a little bit each year, mainly due to inflation. With a good plan, you have a reasonable chance of growing faster than your marketplace.

The title of this article was meant to catch the reader's eye. In reality, if you do not have a plan, you may still make a profit. But an effective plan will create growth, which will allow you 1) more options for restructuring your workforce to make it more effective, 2) distribute a number of fixed costs over a wider base, and 3) slowly expand your labor multiplier. All these activities increase your Return on Net Revenue. Without a plan, you can't do it.

MARKETS

You have to know who you are now and what you want to be later. Maybe you provide hazardous waste consulting services to industry and you would like to add a wastewater practice for the same type of clients. The markets that you define in your plan should be consistent with this vision.

I like to look at the marketplace in two dimensions. One dimension is type of client: industry, government (local, state, and/or federal), professional service firms (lawyers, private equity firms etc.), commercial (land developers etc.), environmental regulatory agencies etc.

The other dimension is by practice area: water, wastewater, solid and hazardous wastes, air pollution control and permitting, site investigations, remediation, climate change, mergers and acquisitions etc.

Think of these two dimensions as forming a matrix with boxes in it. Which boxes are you in? Which do you want to get into? Sometimes the first part of this exercise generates obvious targets for the second part.

Another way to visualize the marketplace is as shown in **Figure 1.** The x axis represents the degree of difficulty to perform the engagement. The y axis represents the willingness of the client to pay higher rates. The upper right corner of the diagram represents the best part of the marketplace: tough projects, not a lot of others able to do them, higher prices are paid. The X is your average project. The idea is to push your firm slowly towards the upper right corner. You won't entirely get there, but the effort will improve your fortunes.

CLIENTS AND PROSPECTS

Your plan needs to define existing clients and specific project opportunities that you want to pursue with them over the coming year. This requires input from the firm's senior professionals (Senior Project Managers, Partners). This list should be based on a sound knowledge of each client and numerous informal discussions with them about their problems and opportunities. It is reasonable to expect that 80%+ of next year's project workload is going to come from this list.

Prospects are different. Based on your market analysis, and knowledge of organizations that fit your current and desired future location in the marketplace, who do you want to pursue as a client? This implies study and *choice*. There is no point in pursuing a purchasing department driven, low cost client if your firm is built to perform high end, higher priced consulting work. Generally, the identification of prospects should come from the most senior members of the firm.

PRICING AND BILLING

This is often left out of marketing and sales plans. This is exceedingly important. What labor rates and mark-ups do you want from existing and new clients? Three fundamental rate structures should be defined clearly: standard, preferred, and litigation support. Standard rates cover existing clients, with no discounts. Preferred rates are approximately 5-10% higher and are aimed at new clients (prospects): they are part of your strategy to force your firm towards the higher end of the marketplace. Litigation rates are at least 50% higher than the standard. Whatever your strategy, your rates and marketing targets must be absolutely consistent with your business plan.

Your plan needs to define existing clients and specific project opportunities...

EXISTING CLIENT DEVELOPMENT

This is for everybody, i.e a requirement for all personnel from project manager upwards. You know your existing and dormant clients. You've listed project possibilities for the coming year. Everyone gets specific assignments to pursue each opportunity. There should be no gaps in this process. There is an Appendix that you attach to the plan which lists all opportunities and the person responsible.

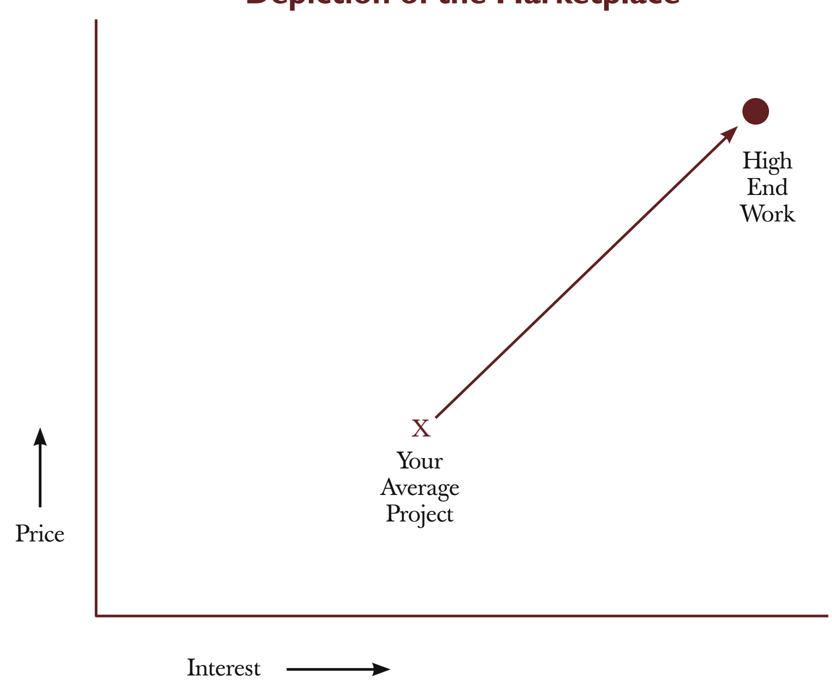
NEW CLIENT DEVELOPMENT

This is not for everybody. Broadly speaking, one can take all the project managers and more senior personnel and divide them into two groups: hunters and farmers. Farmers are good at working with existing clients. They quickly gain the clients' trust and respect and can sell add-ons to existing projects, the next project phase, or related projects. Hunters are different and are usually in the minority. They are more outgoing, aggressive, and less bothered by failure. These are the people that you assign to prospects that have been identified in the marketing plan. You should have enough knowledge of the hunters and prospects to match them properly. There is an analytical component here. It goes something like this.

The firm has 100 clients. It wishes to outgrow the marketplace by about 5% per year.

FIGURE 1

Depiction of the Marketplace



Roughly speaking, you need to add 5 new clients per year plus 10 to cover possible attrition. It takes roughly 150 prospects to turn into 15 clients (10/1 ratio). You should spend about 16 effective marketing hours annually to stay in touch with each prospect, visit with them etc. Thus, the firm needs 2400 hours devoted to marketing of prospects. If you have 10 hunters, that is 240 hours each annually. The utilization goals and sales goals of these individuals should be consistent with this evaluation.

What are the hunters supposed to do with prospects? Get imbedded in their forebrain and obtain their trust. The first requires contact. Go see the prospect three or four times per year. Sit in their office and talk to them about their operations, problems, opportunities. Get them to let you see their facilities. Stay in touch via email. Send them an article of interest – even in today's electronic world, a real newspaper clipping says that you personally cared about the prospect. If nothing comes of your efforts with a prospect after 2 or 3 years, move on to another prospect.

NEW SERVICES AND PRODUCTS

Change or die. If, for example, you want to do nothing but environmental remediation, you may someday find your marketplace to be very small, and highly price (low) driven. If you aspire to be the last great fountain pen maker in the US, you have found your home. For the rest of us, we need to look at the marketplace and ask: What's new? Which of these areas fit the skills of my existing workforce? Can a few key hires get me into another segment? Can I support their projects?

Do not bite off more than you can chew. Generally, only 1-3 new business areas should be pursued at a time. This is a job for your hunters. Sometimes a hunter is a strategic hire, who you believe has enough contacts and clients in your business area to get your firm jump-started. This is a good strategy, sometimes known as buying a part of the marketplace. Give the strategic hire plenty of attention (you've put them in a new culture) and cooperation (some of your partners have to be persuaded to allow her or him to visit their clients). And don't be afraid to admit defeat. Part company, if you haven't reached your sales goals after 2 or 3 years.

> *Marketing is almost always a firm's largest project.*

We don't often think about products in professional service firms. But there are some. Have we accumulated a large amount of regulatory knowledge? Maybe you can package it as a handbook (publisher as partner) and sell it. Use your imagination. This can be a very good supplement to net revenue, and if done correctly, take very little effort after the initial effort to get it off the ground.

BUILDING TRUST AND VISIBILITY

You won't get hired until the prospect trusts you. The fundamental way to build trust is to visit the prospect, talk about their business, and tell them some things that they did not know. A referral from one client to a prospect is not only another way to start this process, but also a frequently overlooked marketing tool.

Exhibitions of professional competence build trust. Read this as giving papers at appropriate conferences, publications, speaking before trade groups and professional organizations, working with your prospects on environmental issues through trade groups or a large Chamber of Commerce. Papers

❖ *Continued on 20* ❖

TABLE 1
Outline of a Marketing Plan

Section 1	Overall Strategy Background Objectives Pricing Guidelines Resources Available Priorities
Section 2	Existing Clients
Section 3	New Client Development
Section 4	Infrastructure Needs & Activities
Section 5	Generalized Activities Seminars Advertising & Publicity Technical Societies/Trade Groups Papers & Publications Marketing Trips
Section 6	Budget and Schedule

2007
STANLEY E. KAPPE AWARD RECIPIENT

Matthew Dominy, P.E., BCEE

Matt Dominy graduated from Bucknell University with a degree in Civil Engineering, and was commissioned into the US Army Corps of Engineers. While in the Corps, he earned a graduate degree in Civil Engineering Management from the University of Florida.

After leaving the Army, he worked as Plant Engineer/Manager for a subsidiary of the American Can Company in South San Francisco, CA. The plant bought tin-plate scrap, chemically separated the tin from the steel, refined the tin back to pure tin, and sold the steel to copper mines to extract the remaining copper ore from the mine tailings. This was his first recycling experience.

Matt spent the next 15 years alternating between municipal public works positions, and working for consultants assisting public works operations. He spent five years on the Board of Directors of the American Public Works Association, was selected as one of the Top Ten Public Works Leaders in North America in 1994, was certified with a specialty in Solid Waste in the Academy in 1996, and was selected to be the APWA Trustee to the Academy in 1999.

At the conclusion of his term representing APWA, Matt served as the Treasurer of the Academy for three years. Working with staff, he oversaw three years of budgets which mitigated the Academy's financial problems, and provided a solid basis for ongoing future operations.

Matt currently works in transportation, but maintains a high level of interest in the environmental aspects of transportation operations across all mediums.

2007 GORDON MASKEW FAIR AWARD RECIPIENT

James F. Stahl, P.E., BCEE

Mr. Stahl is the recently retired Chief Engineer and General Manager of the Sanitation Districts of Los Angeles County. The Districts provide wastewater treatment and solid waste management services for approximately five million people.

He started with the organization in 1969 after receiving his B.S. in Civil Engineering from Loyola University, now Loyola Marymount, and a M.S. in Environmental Engineering from Stanford University. He progressed through various staff and management positions with the agency, culminating in 2000 with his appointment by the Districts Boards of Directors, comprised of the Mayors of the seventy-eight cities it serves, to the position of Chief Engineer and General Manager.

Mr. Stahl has authored scores of technical publications and presentations on the Districts' many engineering accomplishments and environmental safeguards. He has been active in professional organizations and committees. He was President of the California Association of Sanitation Agencies and President of the Southern California Alliance of Publicly Owned Treatment Plants. He was a member and Chairman of the Board of Directors of the Water Environment Research Foundation.

He is a member of the Water Environment Federation and served on the Technical Practice and Program Committees. He was the recipient of the American Academy of Environmental Engineers 2001 Edward J. Cleary Award and most recently was elected to the National Academy of Engineering. He and his wife Shelley reside in the city of Rancho Palos Verdes, CA. and have four sons, Nick, Bryan, Patrick and Kevin.

2007
EDWARD J. CLEARY AWARD RECIPIENT

Leo Weaver, P.E., BCEE

Leo Weaver obtained his Civil Engineering degree at New York University in 1948 after returning from his service in the Army Combat Engineers in the European Theatre in WWII. He was commissioned an Engineer Officer in the US Public Health Service in 1948. During his USPHS career, he served as Director of the National Water Pollution Surveillance System Laboratory at Cincinnati, Ohio, 1960-1965, Chief of the Facilities Demonstration Grant Program (storm water) of the Federal Water Pollution Control Program (1966) and Chief of the Solid Waste Program (1967), Washington, DC.

Following his retirement from the USPHS in 1968, Leo was Director of the Washington, DC Office of the American Public Works Association, 1968-1971. From 1971-1974 he was Assistant Executive Secretary of the Water Pollution Control Association and responsible for the Federation's Government Affairs. In 1974 Leo was named Executive Director and Chief Engineer, Ohio River Valley Water Sanitation Commission (ORSANCO), an interstate compact water pollution agency headquartered in Cincinnati, Ohio. Following his retirement from ORSANCO in 1987, he established a practice as an Environmental Engineer Consultant. He fully retired in 1998.

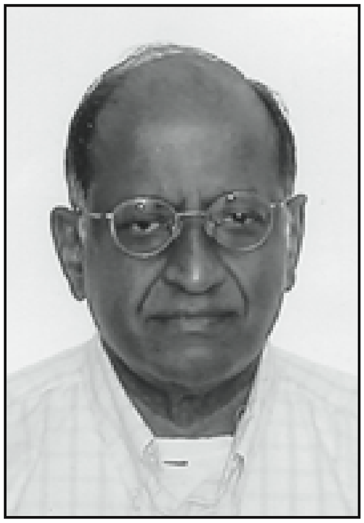
Leo and Mary Lou, his wife of 58 years, moved to Greeley, Colorado in 1999 to be closer to family. He has continued to practice Environmental Management serving as chairman of Greeley's Storm Water Board and the County Board of Health.

Leo was licensed to practice in New York and Ohio. He was certified by AAEE January 1, 1974 and served as AAEE President in 1986.

2007

HONORARY BOARD CERTIFIED ENVIRONMENTAL ENGINEER

Daniel J. Gunaratnam, Ph.D., P.E., BCEE



Dr. Daniel Gunaratnam was educated in Australia and obtained his Bachelor of Engineering (1962) and Masters in Hydrology (1966) at the University of Adelaide (South Australia). Subsequently he obtained his PhD at Mass Institute of Technology 1970 in Water Resources and Hydrodynamics. His work experience (1963-2006) covers some 15 countries working for Asian Development Bank (4 years), World Bank (20 years), and Private Consulting (7 years) and in University Teaching (5 years) in water resources and environmental engineering.

Since retirement from the World bank in 2001 he has been a water resources and environmental consultant advisor for the World Bank, Asian Development Bank and private firms on water resources, environmental engineering and policy, and in resettlement livelihood restoration. One of the major jobs he is involved with presently is to advise the State Environmental Protection Agency China on development of institutions and procedures for environmental pollution control.

Between 1989-2001 he was working with the World Bank as a Principal Water Resources Engineer and was the Task Manager for some of the largest Water Resources cum Environmental Projects most of which are centered in China (1987-2001). He was the Taskmanager for the 10-12 projects valued six billion dollars of water resources cum environmental projects. Noteworthy amongst these projects was the only silt /flood regulation dam project ($2.5 billion) on the Yellow River to reduce the risk of flooding for protecting some tens of millions of people and with comprehensive environmental management plan. Associated with this project he Task Managed a very successful Resettlement Project ($1 billion) for some 65,000 families. Another noteworthy project was largest desert regreening project in the Taklamakan Desert also in China. A

and publications live on and on: after the initial presentation and/or publication, copies can be used to inform prospects.

Who are the influential trade groups for your clients? If you are active in the petroleum industry, you should have someone designated to work with the American Petroleum Institute.

INFRASTRUCTURE TASKS

This should be part of your plan. This can include new or updated Statements of Qualifications, summaries of key projects, updated contact tracking software etc. These kinds of things can be done by a very small marketing support staff. In general, the author is not a fan of highly paid marketing specialists whose only function is to sell work for the firm, with someone else doing it. Much of the environmental marketplace does not respond to this. They want to talk to someone who knows their environmental problems and how to solve them.

MANAGEMENT OF THE MARKETING PROCESS

Marketing is almost always a firm's largest project. And it usually does not have a Project Manager! The activity is dispersed among many individuals (as it should be), but nobody is in responsible charge. This needs to be fixed. A very senior individual in the firm must be in charge and have the authority to do something when parts of the plan are being executed poorly. There must be clear goals, budgets, and schedules for everyone involved, with the Marketing Project Manger seeing to it that they are implemented.

The firm's business plan must clearly show the number of hours allocated to marketing for the entire firm, and the out of pocket costs associated with it (travel, publications, meals etc.). Individuals should know how many hours each year that should be devoting to marketing, billable work etc. All the numbers have to be consistent with each other.

Everyone needs to be trained for the job. This is often underemphasized. The training could be done internally or externally. Hunters and farmers alike have to be shown that the marketing emphasis is on experience and benefits to clients, not credentials. The credentials (such as the Academy's BCEE) are necessary, but not sufficient conditions for generating engagements. In the end, the client wants to see experience and how it would be applied to their situation.

SUMMARY

We did not cover proposals and contract negotiations here. That is part of the sales process and out of the scope of this article.

Marketing can and should be a natural client or prospect problem solving exercise which utilizes the firm's senior personnel to generate more work. The whole exercise should use the project management skills possessed by these personnel and one person should be in overall charge.

About the Author

Brian P. Flynn, P.E., BCEE, is an environmental engineer and management consultant/trainer concentrating on improving the efficiency and profitability of environmental engineering firms. He practices his specialty world-wide from an office in the Denver area. He can be reached at BFlynn4290@aol.com. A

2007 Excellence in Environmental Engineering®

A GRAND PRIZE
is awarded in each category.

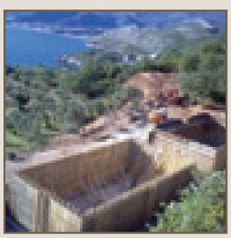
SUPERIOR ACHIEVEMENT FOR EXCELLENCE IN ENVIRONMENTAL ENGINEERING
is awarded to the best entry.

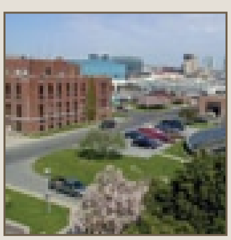
AN HONOR AWARD
is awarded to others deserving of commendation.

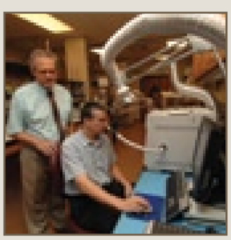
THE EXCELLENCE IN ENVIRONMENTAL ENGINEERING® competition of the American Academy of Environmental Engineers exists to identify and reward the best of today's environmental engineering. Its criteria define what it takes to be the best in environmental engineering practice: a holistic environmental perspective,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

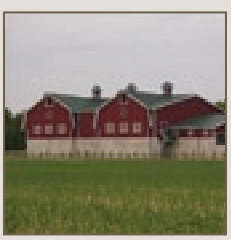
The competition, begun in 1989, is organized around the normal phases of development and implementation of environmental management projects and programs: research, planning, design, and operations and management. This year's entrants to the competition displayed a wide range of projects from innovative designs in waste treatment plants to new water treatment technologies to a one-of-a-kind Superfund site cleanup. 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 make these projects the award winners they are.

Those chosen for prizes in 2007 by an independent panel of distinguished 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

2007 Excellence in Environmental Engineering®

ENTRANT: Donohue & Associates, Inc.
ENGINEER IN CHARGE: David J. Speth, P.E.
PROJECT NAME: 1st "Glass" Biosolids Vitrification Facility
LOCATION: Zion, Illinois

1ST "GLASS" BIOSOLIDS VITRIFICATION FACILITY

Zion, Illinois

The North Shore Sanitary District was seeking alternative means to improve its biosolids disposal practice. Alternatives were evaluated and eliminated for their significant shortcomings from an environmental and/or financial perspective.

NSSD determined that their best alternative was to use a biosolids drying and melting (vitrification) process, resulting in the successful implementation of the most environmentally sound biosolids disposal method ever developed. Each day, the facility converts up to 200 tons of municipal biosolids into 7.5 tons of reusable glass aggregate. This is the first facility of its kind in the world.

This collaborative project between Donohue & Associates, Inc. and the District has resulted in the successful conversion of a waste product to a useful product without harmful environmental issues associated with it.

The glass aggregate has no risk of soil or groundwater contamination since microorganisms, such as bacteria and viruses, are destroyed through the heating processes. Trace metals and other inorganic materials are permanently stabilized within the glass matrix and can not seep into the environment.

The biosolids drying and melting process offers many benefits to municipal wastewater treatment systems, including: eliminating long-term dependence on landfill disposal, providing residents and local industries with a cost-effective alternative for managing biosolids, and providing public agencies with a more comprehensive and integrated approach to solid waste management.

The building housing the facilities was designed to blend into a future business and industrial park under development in the surrounding area. The glass aggregate process meets all applicable government regulations for air quality and solid waste management. To protect the environment, the facilities have highly effective air emissions, odor control, and mercury removal systems.

TOP LEFT
Due to site constraints, the project required the integration of three major and five minor unit processes within a 35,000-square-foot building.

BOTTOM LEFT
The North Shore Sanitary District is the first municipality in the world to construct a biosolids drying and vitrification facility. The highly attractive building was designed to blend into a future business and industrial park under development in the surrounding area.

TOP RIGHT
The glass aggregate (shown here) has no risk of soil or groundwater contamination since microorganisms are destroyed through the heating processes. Trace metals and other inorganic materials are permanently stabilized within the glass matrix during vitrification and can not leach into the environment.

ENTRANT: Brown and Caldwell
ENGINEER IN CHARGE: John Willis, P.E., BCEE
PROJECT NAME: Columbus Biosolids Flow-Through Thermophilic Treatment (CBFT) Advanced Demonstration Preliminary Design Project
LOCATION: Columbus, Georgia

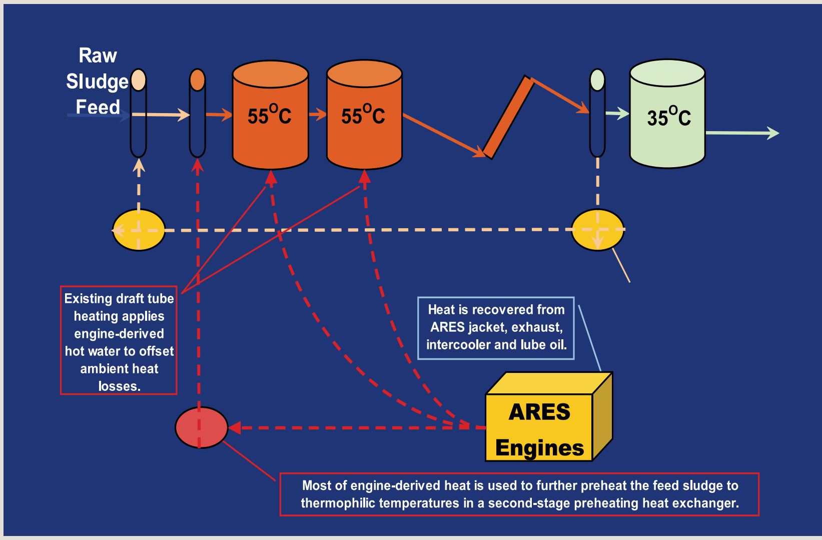
COLUMBUS BIOSOLIDS FLOW-THROUGH THERMOPHILIC TREATMENT (CBFT) ADVANCED DEMONSTRATION PRELIMINARY DESIGN PROJECT

Columbus, Georgia

Columbus Water Works (CWW), along with environmental engineering firm Brown and Caldwell, are in the midst of developing the process known as Columbus Biosolids Flow-Through Thermophilic Treatment, or CBFT^3.

CBFT^3 destroys the pathogens in sewer sludge, thus improving CWW's biosolids' designation from Class B to Class A, which is signficant because CWW relies on land application for reuse of biosolids from its South Columbus Water Resource Facility (SCWRF). Land application is an environmentally friendly way to reuse biosolids, which are not only rich in nitrogen and phosphorous, they help reduce the amount chemical fertilizers applied to land. Land application also prevents biosolids from accumulating in already over-crowded landfills.

Treatment of wastewater to high water quality standards requires the generation of sludge. Retrofitting the existing digestion system will provide increased sludge reduction and pathogen destruction. Methane-rich digester gas will be captured and used to fire lean-burn combustion engines for energy generation. Advanced Reciprocating Engine Systems (ARES) units, which represent the first digester gas application in the United States, will produce the cleanest engine exhaust emissions ever produced with digester gas. Waste heat from the engines will be fully-recovered and used to heat the CBFT^3 process. CHP recovery will generate 40% of the SCWRF's electricity needs and 100% of the energy needs for process heating.



TOP
Heating and cooling for the CBFT3 process is provided by two distinct heating systems. The first preheats feed sludge using heat derived from cooling thermophilic sludge to mesophilic temperatures. The second uses all available engine heat sources to achieve and maintain thermophilic temperatures.

LEFT
During the investigation phase, a rendering of future plug-flow digesters was developed. It was later determined that only two such reactors would be needed to meet a 30-minute batch time for stand-alone, Class-A performance.

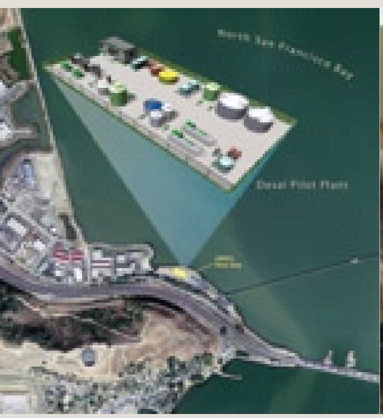
RIGHT
A variety of internal baffle configurations were tested using digesting sludge during the prototype reactor tracer studies, including: 1) Without baffles; 2) With one solid baffle; 3) With one open-center (meaning that the 8-inch-diameter flanged opening in the baffle tip was removed) baffle; and 4) With two open center baffles. A single open-center baffle provided the best performance.

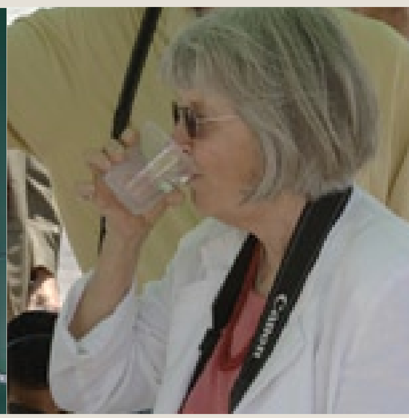
ENTRANT: Kennedy/Jenks Consultants
ENGINEER IN CHARGE: Joel A. Faller, P.E.
PROJECT NAME: MMWD Seawater Desalination Pilot Program
LOCATION: San Rafael, California

MMWD SEAWATER DESALINATION PILOT PROGRAM

San Rafael, California

The MMWD Seawater Desalination Pilot Program was a successful year-long study to test advanced treatment for the challenging San Francisco Bay source water, confirm the treated water quality, perform environmental studies and prepare design criteria for a full-scale facility. blended with effluent from the local wastewater treatment plant will not harm the San Francisco Bay environment. The report recommends the best pretreatment process for water from upper San Francisco Bay and presents preliminary design criteria and conceptual costs for a full-scale desalination facility.





MMWD hired Kennedy/Jenks Consultants to lead a team of consultants, which included CH2M Hill and MMWD's own staff, in conducting the Seawater Desalination Pilot Program. URS Corporation, working under a separate contract, assisted with the public outreach seminars and helped prepare the project EIR.

Kennedy/Jenks designed, constructed, and operated the pilot program from June 2005 to May 2006. The pilot program included a water quality test program that is probably the most comprehensive program conducted for a seawater desalination pilot plant. It included extensive environmental testing to support the Environmental Impact Report (EIR) for the project. It also developed substantial analytical evaluations of the pilot data and design criteria and produced a thorough and comprehensive Engineering Report with detailed cost estimates for full-scale project alternatives.

The SWRO Pilot Program used a comprehensive, integrated approach that not only tested the safety and taste of the desalinated water, but also investigated the effects that a full-size desalination facility would have on the water quality in San Francisco Bay, air quality in Marin County, and the landfill where solid wastes from the desalination process would be sent. The study showed that desalinated water is safe and meets all state and federal requirements. It also demonstrated that brine discharge

LEFT
A SUCCESSFUL YEAR-LONG PILOT STUDY
The Marin Municipal Water District (MMWD) ran a successful year-long pilot study that tested seawater desalination using reverse osmosis (RO) technology. To locate the plant near their distribution system and to reduce energy requirements, Marin chose to use water from north San Francisco Bay, a very challenging, constantly changing water source. The program confirmed the quality of the treated water, performed extensive environmental testing, and prepared design criteria for a full-scale facility.

SECOND
SWRO'S INCREASING ROLE
Seawater desalination is an increasingly important tool for providing communities around the world with a safe, reliable, water supply.

THIRD
SIDE-BY-SIDE TESTING OF PRETREATMENT PROCESSES
The pilot program was designed with several parallel pretreatment processes to decide on the optimal processes. To get a specific comparison of pretreatment methods, the program did side-by-side testing of conventional units and MF and UF units to determine the best pretreatment for this source water. This photo shows the conventional pretreatment process.

RIGHT
INTAKE FISH ENTRAINMENT STUDY
Unlike open ocean SWRO plants, MMWD cannot use an existing power plant intake. MMWD would draw water directly from the Bay. The project completed an entrainment study to test whether the screened intake would protect fish in the Bay. The test results should be helpful for other projects with screened intakes.

GRAND PRIZE planning

2007 Excellence in Environmental Engineering®

ENTRANT: CDM and CH2M Hill
ENGINEER IN CHARGE: Heather Boyle VanMeter, P.E.
PROJECT NAME: Los Angeles Integrated Resources Plan
LOCATION: Los Angeles, California

ENHANCED NUTRIENT REMOVAL FOR THE PATAPSCO WASTEWATER TREATMENT PLANT

Los Angeles, California

The residents of Los Angeles collaborated to establish a stakeholder-based integrated resources plan (IRP) that identifies the interdependent needs of the city's wastewater, recycled water, and stormwater systems.

Led by the city of Los Angeles and the joint venture team of CDM and CH2M HILL, the Los Angeles IRP is a technically and environmentally sound, cost-efficient approach to water resources planning. Through focused facilities, environmental impact, and financial planning, the IRP identified best practices to optimize existing service functions. It emphasizes the benefits of water reclamation, treating recycled water and urban runoff to provide additional water supply for the semi-arid region while reducing pollution and costly dependence on imported water.

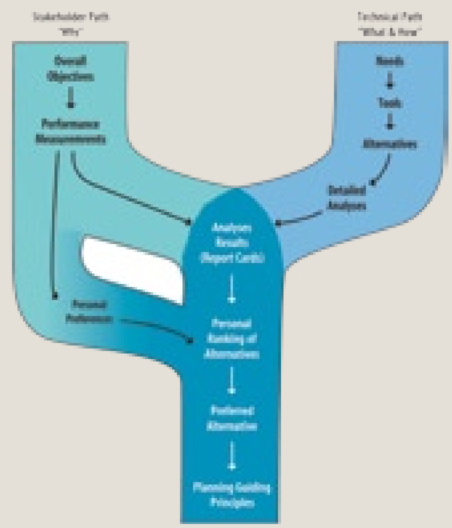
Integral to the IRP research and planning process, community leaders were organized to form steering, advisory, and information groups to facilitate feedback and suggestions to the city. During a 4-year period, the IRP led 13 half-day workshops and more than 120 community meetings, and disseminated periodic newsletters that highlighted project milestones and recommendations to build city and stakeholder consensus.

Future facilities will provide new sewers and wastewater treatment for an additional 50 million gallons per day (mgd), increase recycled water use by 120,000 homes per year, potentially conserve more than 15 mgd of drinking water, and manage up to 800 mgd of stormwater and urban runoff.

LEFT CLIENT NEEDS
The effects of aging facilities, funding constraints, and pollution perpetually challenge current and future water supplies, recycling and conservation practices, and runoff management programs for the rapidly growing city, estimated at 19 percent growth by 2020.

RIGHT ENHANCING EXISTING PROCESSES/FACILITIES
Treatment plant optimization at the Tillman water reclamation plant, San Fernando Valley, and Playa del Rey facilities provides new storage, improved operations, and cost savings.

BELOW SOLUTION
Working with the joint venture team of CDM and CH2M Hill, the city embarked on a landmark stakeholder-based integrated resources plan (IRP). Grounded in urban sustainability achieved through interagency coordination and intensive public participation, the unique IRP process determined intra- and interagency redundancies and gaps, enabling an unprecedented, holistic approach to Los Angeles' water resources planning that maximizes taxpayer funds without jeopardizing environmental media or public health.



GRAND PRIZE design

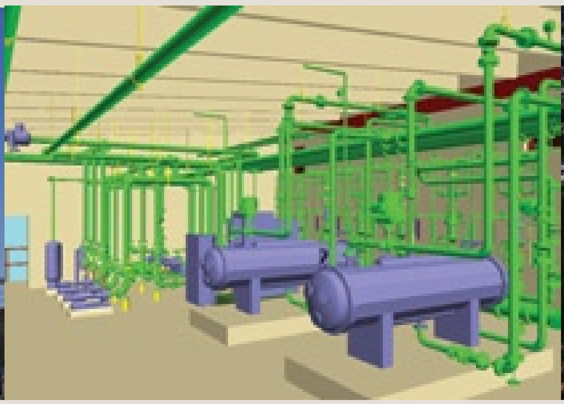
2007 Excellence in Environmental Engineering®

ENTRANT: Jordan, Jones and Goulding, Inc., CH2M Hill, Inc. and Precision Planning, Inc.
ENGINEER IN CHARGE: Don Joffe, P.E.
PROJECT NAME: F. Wayne Hill Water Resources Center (FWH WRC)
LOCATION: Buford, Georgia

F. WAYNE HILL WATER RESOURCES CENTER (FWH WRC)

Buford, Georgia

Gwinnett County has faced many challenges over the last decade. In response, it constructed the F. Wayne Hill Water Resources Center (FWH WRC), a state-of-the-art, 20 million gallons per day (MGD) water reclamation and processing facility. The FWH WRC, which is meeting the state's most stringent wastewater treatment limits, was specifically designed to protect water quality, protect public water supplies, and provide the potential for indirect re-use of the treated effluent through discharge to Lake Lanier.



The Team of Jordan, Jones & Goulding, Inc., CH2M HILL, Inc. and Precision Planning, Inc. (Team) were responsible for the conceptual planning, pilot testing, equipment pre-selection, process and equipment alternatives analysis, cost estimating, I&C configuration, design, construction contract administration, construction contract sequencing, operations guide preparation, and start-up assistance. Working with the County Engineering and Operations staff and the construction contractors and suppliers, the Team was able to deliver this $365 million facility within a 5 year timeframe - approximately 1 year early.

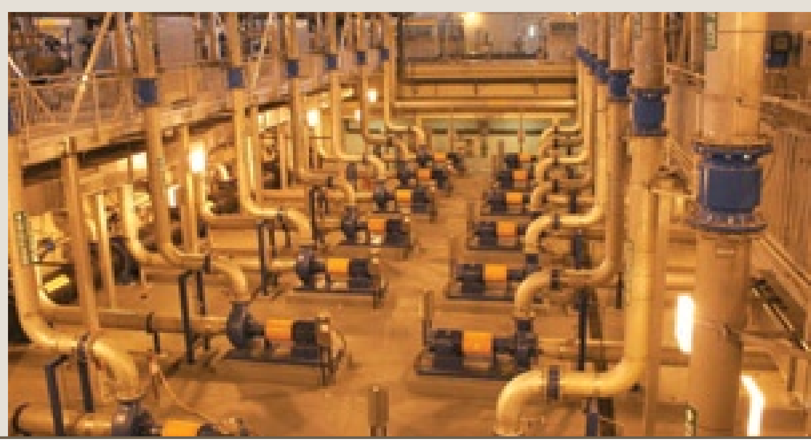
An on-site design team was utilized to complete the design for the 40 MGD expansion. Construction of Phase 1 was still in progress at the beginning of the Phase 2 design and on-site conditions were constantly changing. The design team had complete access to operating staff and was able to incorporate many of their ideas and expedite reviews. New 3D design technology was utilized to aid in checking for interferences with Phase 1 work, derive a more accurate sequencing of construction and help the contractor visualize complicated structures which in turn allowed the $365 million construction project to be completed on time and on budget. To expedite the construction period, four sequenced construction contracts were issued and major equipment was pre-selected. Designs were completed utilizing accurate vendor submittals following workshops between suppliers and design staff.

LEFT
The waste activated sludge from the BNR process is combined with primary sludge and stabilized in eight, egg-shaped anaerobic digesters.

MIDDLE
3-D Model of Ozone for Final Disinfection

RIGHT
JJG has provided Gwinnett County the innovative and cutting-edge solutions in the FWH WRC design that raise the standard of excellence in wastewater treatment. The selected advanced wastewater treatment process train included, 3-stage biological nutrient removal (BNR) process, 50-MGD tertiary membranes, ozone ahead of granular activated carbon, and ozone for final disinfection.

BOTTOM
The 50 MGD ultra-filtration membrane system is a state-of-the-art facility consisting of fine screens, membranes, CIP and cleaning systems housed in a separate building.



ENTRANT: CDM
ENGINEER IN CHARGE: Myron S. Rosenberg, Ph.D., P.E., BCEE
PROJECT NAME: Coastal Development and Environmental Improvements Project
LOCATION: Budva, Montenegro

COASTAL DEVELOPMENT AND ENVIRONMENTAL IMPROVEMENTS PROJECT

Budva, Montenegro

CDM's Coastal Development and Environmental Improvements Project for the U.S. Agency for International Development (USAID) successfully addressed imminent health threats and improved vital services for Budva, Kotor, and Cetinjer. CDM led the complex design-build efforts of the 22-month, $8 million infrastructure improvement project. To further foster economic activities and involve the community, CDM employed local subcontractors and employees, resulting in 9,400 person-months of employment for locals during construction and 45 full-time positions after project completion, as well as $5.5 million of construction-related income for the region.

Throughout the project, CDM overcame significant challenges to deliver unique solutions tailored to the communities' abilities to operate and maintain the systems. As a result of the project, statistics reflect that drinking water interruptions of 1 hour or more during the tourist season dropped by as much as 96 percent and infrastructure improvements saved 15 liters of drinking water per second, providing enough water to supply 13,000 tourists. In communities where interruptions in wastewater pump station service had previously caused sewage overflow and polluted beaches during the tourist season, system upgrades reduced the number of days that had service interruptions of 1 hour or more during the tourist season by more than 90 percent – a remarkable achievement for Montenegro, where interruptions are common hazards.

TOP RIGHT
CDM considered the impact on sites of historical significance throughout the projects. Shown here is the completed Trojica Reservoir in Kotor. The building in the foreground is a 19th century Austro-Hungarian fort, which is under the protection of the Montenegrin Institute for Cultural Heritage.

BOTTOM LEFT
To foster economic activites, CDM employed local subcontractors and employees, such as during the construction of the Trojica Reservoir in Kotor, as shown here.

BOTTOM RIGHT
CDM's streamlined approach allowed for concurrent project implemenation, allowing benefits to be realized by the 2005 tourist season. Improved infrastructure, such as the completed Budva II wastewater pumping station on Slovenska beach shown here, allowed Montenegro to accomodate a 17-percent increase in tourist visits.

ENTRANT: CH2M Hill
ENGINEER IN CHARGE: Brian Gackstatter, P.E.
PROJECT NAME: Stamford Water Pollution Control Facility Upgrade and Expansion Project
LOCATION: Stamford, Connecticut

STAMFORD WATER POLLUTION CONTROL FACILITY UPGRADE AND EXPANSION PROJECT

Stamford, Connecticut

CH2M HILL partnered with the Stamford Water Pollution Control Authority to provide engineering design and services during construction for a $105 million upgrade and expansion of the 30-year-old Stamford Water Pollution Control Facility, $60 million of which is associated with nitrogen removal processes. The City hired CH2M HILL in 1996 for the massive project, though the partnership between Stamford and CH2M HILL began in 1989 through proactive projects addressing nitrogen removal in the Long Island Sound.

The Stamford Water Pollution Control Facility (WPCF) treats wastewater from 80 percent of Stamford's population including the sewered portion of the city and wastewater flows from Darien, Connecticut. Under the recently completed upgrade and expansion, the plant's average capacity expanded from 20 to 24 million gallons per day (mgd) with peak flow capacity of 68 mgd. In addition, Stamford WPCF was upgraded to enhance nitrogen removal, solids handling, and improvements to other functions of the plant in accordance with the City's and Connecticut Department of Environmental Protection (CTDEP) requirements. The upgrade and expansion comprised the most ambitious and sophisticated upgrade in the plant's history.

The upgrade and expansion project will have several positive impacts on the Stamford community, including environmental enhancements to the region and community, the opportunity for waterfront revitalization, the capacity to support growth in the City, and economic benefits through the State of Connecticut's unique nutrient removal credit trading program.

TOP
ORIGINAL PLANT
The Stamford WPCF treats wastewater from 80 percent of Stamford's population. The site of the WPCF has been treating wastewater for over 100 years. The first wastewater treatment facility was built around 1890 and was completely rebuilt in 1943 and 1976.

LEFT
ODOR CONTROL
The Stamford waterfront is enjoying a revitalization due to the aesthetic and environmental improvements brought about by this project. With a notable reduction in odor, the area can anticipate an increase in fishing, tourism, and recreation.

MIDDLE
UV BASIN CONSTRUCTION
Ultraviolet disinfection system basin during construction and installation.

RIGHT
PLANT ENTRANCE
Aesthetics and visual impacts were important to this upgrade. Stamford WPCA takes great pride in the plant architecture and the natural beauty of the area and recognizes the visual impact its facilities have on the community. New buildings were designed to match the architecture of Stamford. The plant blends into the landscape, fitting in with other architecture in the area rather than looking like a typical treatment plant.

ENTRANT: Delaware Solid Waste Authority
ENGINEER IN CHARGE: Pasquale S. Canzano, P.E., BCEE
PROJECT NAME: Route 5 Transfer Station
LOCATION: Harbeson, Delaware

ROUTE 5 TRANSFER STATION

Harbeson, Delaware

The Delaware Solid Waste Authority determined there was a need to provide a solid waste transfer station in Sussex County Delaware in order to assist its customers nearer the Delaware beaches and resorts. The distance from the explosively growing beach community to the landfill was cause for increased truck traffic and associated transport costs for the waste-generating communities. The increased truck traffic required to haul the solid waste to the landfill increased the engine exhaust or hydrocarbon emission into the atmosphere as well.

The DSWA found a suitable site that contained nearly 300 acres of land near Georgetown, Delaware. This site was ideally located near the resort area, on a state road and included a parcel large enough to accommodate the facility needs.

The DSWA recognized that developing this site would be met with an organized opposition, as other projects had been rejected citing community concerns over increased traffic activity. Therefore, DSWA formed a committee of local community leaders and listened carefully to their concerns. At the committee's regular meetings, DSWA addressed the community's concerns one-by-one, until the objections dissipated. In fact, DSWA presented its own ideas and concepts that ended up garnering support for the design. These ideas included designing the main transfer building to have the appearance of a barn and to set aside the bulk of the acreage for agriculture land preservation.

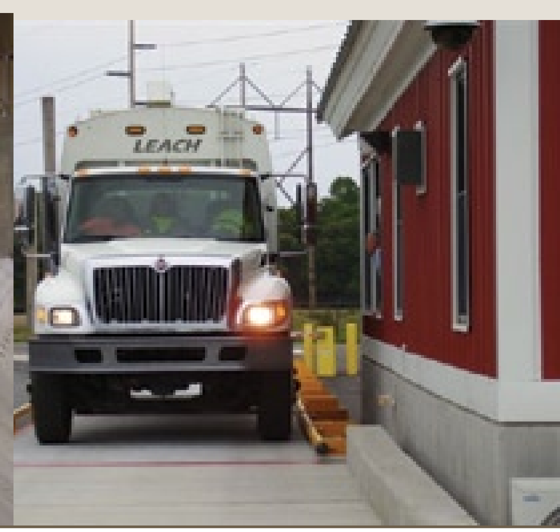
The transfer station building was to be set back from the main road, which served to provide queuing for truck traffic to prevent backing waste haulers onto the main road while waiting to offload. The entrance to the building for trucks was placed away from the roadway and against a wooded portion of the site. This also aided the visual impact and queuing. The best compliment for the site is that most people do not recognize the site for what it is.

TOP
Aerial view of the back of the route 5 transfer station (The bay doors face away from the road)

BOTTOM LEFT
Route 5 transfer station

BOTTOM MIDDLE
Solid waste drop

BOTTOM RIGHT
Waste truck on scale



ENTRANT: Iowa State University
ENGINEER IN CHARGE: J. (Hans) van Leeuwen, Ph.D., P.E., BCEE
PROJECT NAME: Purification of Alcohol with Ozonation and Activated Carbon
LOCATION: Ames, Iowa

PURIFICATION OF ALCOHOL WITH OZONATION AND ACTIVATED CARBON

Ames, Iowa

J. (Hans) van Leeuwen, Jacek A. Koziel, Shinnosuke Onuki and Lingshuang Cai investigated purification of alcoholic beverages, fuel ethanol and recovered solvent alcohol from pharmaceutical extraction. Ozonation with granular activated carbon (GAC) was studied to selectively oxidize and adsorb the impurities, emphasizing undesirable odors, to discover a more cost-effective pathway to purification. The treatment was evaluated by solid-phase microextraction (SPME) to sample headspace above alcohol and subsequent analysis of the vapors and aroma compounds by gas chromatography-mass spectrometry and olfactory (SPME-GC-MS-OL) evaluation of most components.

The team designed, constructed, and optimized an ozonation system including an ozone generator with all air/oxygen pretreatment requirements, porous diffuser contacting column and a GAC column. Much of the equipment, including the ozone generator, was built with the purpose of minimizing introduction of volatile organic compounds from construction materials.

The first phase of the research was aimed at improving the quality of inexpensive alcoholic beverages. The second phase investigated if a shortcut, cost-effective process to make industrial or even food-grade alcohol from fuel ethanol. The third phase investigated alcohol purification in the pharmaceutical industry. Alcohol is used to extract herbal substances of health benefit from plant biomass.

The ozonation + GAC process is cheaper and beneficial to the environment. Energy requirements for processing would be 200 times lower, and savings for the US alcohol industry at 250 million gallons per year would be as much as eliminating one whole mid-sized power plant. This would not only make a contribution towards reducing greenhouse gases and global warming, but greater reuse of materials and more efficient production would also be resource friendly on raw material use.

TOP
Ethanol samples are analyzed on a gas chromatograph-mass spectrometryolfactometry system to determine the removal rates of odor-causing impurities during the purification of ethanol with ozone and granular activated carbon on odor-causing impurities. (Drs. van Leeuwen and Koziel, Iowa State University)

LEFT
Volatile organic compounds (VOCs) are extracted by SPME fiber through Headspace extraction. Also, amber glass vials are used to avoid the infection by light.

MIDDLE
Ozone is introduced to a column of ethanol. Ozone reacts with some impurities in ethanol. No ozone is released from even a shallow reactor.

RIGHT
Aroma panel. A researcher chooses a characteristic of the odor from 64 kinds of odor on the aroma panel. The researcher decides the intensity using the bar located at the right side of the panel.

GRAND PRIZE small projects

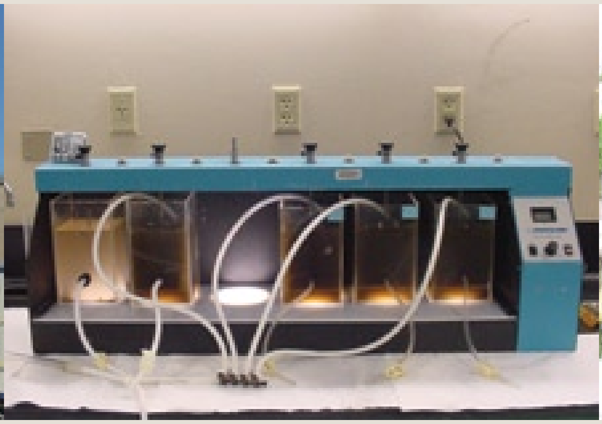
2007 Excellence in Environmental Engineering®

ENTRANT: CH2M Hill
ENGINEER IN CHARGE: Thomas Sigmund, P.E.
PROJECT NAME: Milwaukee Metropolitan Sewer District Study of High-Rate Treatment of Wet-Weather Flows
LOCATION: Milwaukee, Wisconsin

MILWAUKEE METROPOLITAN SEWER DISTRICT STUDY OF HIGH-RATE TREATMENT OF WET-WEATHER FLOWS

Milwaukee, Wisconsin

The Milwaukee Metropolitan Sewerage District (MMSD) operates two wastewater treatments plants (WWTPs) with a combined peak hour capacity of 630 mgd. Following major storms, wastewater flow into the system can exceed 1 bgd. Significant system storage capacity offsets the need to provide treatment capacity equal to the peak daily flow. Accordingly, MMSD is evaluating alternatives for increasing treatment capacity during major storms.



LEFT
The DensaDeg system attaches chemical sludge produced within it (recirculated inside the clarifier) to the incoming solids to increase density and enhance removal. The ACTIFLO system, on the other hand, incorporates microsand in the floc to increase density of the flocs to enhance removal.

MIDDLE
In bench-scale evaluation of biologically enhanced CEC, activated sludge contacts wet-weather flow before undergoing CEC treatment.

RIGHT
During wet-weather events, additional analysis was performed for inactivation of viruses, *Cryptosporidium, and Giardia.*

The Milwaukee Metropolitan Sewerage District (MMSD) partnered with CH2M HILL to evaluate alternatives for increasing treatment capacity during major storms. CH2M HILL conducted comprehensive demonstration tests over a 14-week period to evaluate chemically enhanced clarification (CEC) of wet-weather flows, and the MMSD lab performed analysis of approximately 5,000 test samples.

The CEC demonstration testing program evaluated the performance of selected CEC technologies, evaluated the feasibility of using ultraviolet (UV) disinfection methods on CEC effluent (treated sewage), determined key design criteria for full-scale application of CEC and UV disinfection for wet-weather flows, and compared the performance of CEC/UV treatment with existing treatment processes.

Upon completion, the project demonstrated the feasibility of physical/chemical processes as a cost-effective alternative to traditional biological secondary treatment solutions under wet-weather conditions. As the study showed, CEC can remove pathogens at levels equal to or better than biological secondary treatment.

BELOW
Like the DensaDeg® system, the ACTIFLO® system employs CEC, a physical-chemical treatment process in which coagulants and flocculants are used to create conditions under which dense flocs with a high settling velocity are formed.

ENTRANT: CH2M Hill
ENGINEER IN CHARGE: Don Cuthbert, P.E.
PROJECT NAME: Metropolitan Sewer District of Greater Cincinnati Wet-Weather Storage and Treatment Facility
LOCATION: Cincinnati, Ohio

METROPOLITAN SEWER DISTRICT OF GREATER CINCINNATI WET-WEATHER STORAGE AND TREATMENT FACILITY

Cincinnati, Ohio

The Metropolitan Sewer District of Greater Cincinnati (MSD-GC) selected CH2M HILL to provide comprehensive design services to address the wet-weather overflow and capacity limitations of sanitary sewer overflow (SSO) 700, Cincinnati's largest and most active SSO. In a typical year, 51.2 million gallons of untreated sewage overflow into local waterways from SSO.

The MSD-GC/CH2M HILL team conducted water quality studies, developed and analyzed sophisticated computer models of the sewer system, performed cost-benefit analyses of a broad range of storage and treatment alternatives, and delivered a solution that meets MSD-GC's high-priority remediation needs. State-of-the-art ACTIFLO® Chemically Enhanced High-Rate Settling (CEHRS) equipment is being used at a treatment facility designed to capture and treat significant SSO 700 wet-weather wastewater flows. The facility can handle flows generated from major storms, which usually occur only once every 10 years or so. The CEHRS process requires short detention times, produces high-quality effluent (treated sewage), and employs a cost-saving ultraviolet (UV) disinfection process. This facility is the first in the nation to use this technology to control and treat SSOs at a remote location in the collection system.

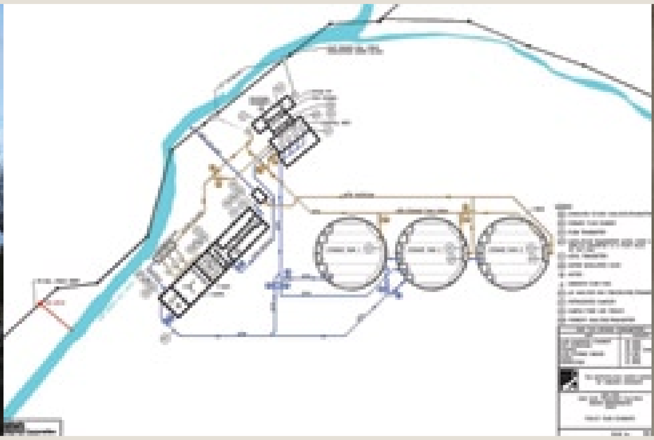
This $1.23 million project helped MSD-GC realize significant water quality benefits in the shortest possible timeframe and at the lowest possible cost. The $10.2 million construction of this design is also lower than the projected $50 million in construction costs for retention basis construction and pipe installation.

LEFT
An 87-foot-diameter dome cover is being placed on top of the storage tank shown on the left-hand side. Stairs on the dome provide access to level detection equipment.

MIDDLE
Flow schematic showing the sewer line coming in from the Mill Creek East Branch. Flows are intercepted and conveyed to the diversion changer. Each storage tank holds 1.2 million gallons of storage.

RIGHT
A flush gate, which is used to remove solids that have settled in the storage tank.

BOTTOM
Construction of the holding tanks. Inside the tanks are influent piping (stacked inside the tank) and concrete flush panels (in the tank floor.)



Volume 2, Spring 2007

Environmental Engineer: Applied Research and Practice

APPLIED RESEARCH AND PRACTICE SECTION

Useful Peer Reviewed Papers Emphasizing Technical Real-World Detail

The Academy is pleased to launch a new section of *Environmental Engineer,* focused on applied research and practice in environmental engineering. The Academy Publications Committee recognized the need for a peer reviewed publication focused on practical research and useful case studies related to environmental engineering. The Academy Board concurred, an editorial board was formed and papers were solicited.

Many archival engineering journals emphasize fundamental research and view reports on successful engineering projects as inappropriate for peer reviewed publication. On the contrary, the Applied Research and Practice Section of *Environmental Engineer* encourages publication of useful reports and applied research with an emphasis on technical, real-world detail. Quality is ensured by peer review and by an Editorial Board of experienced practitioners and educators.

It should be pointed out that the Academy is not alone in recognition of the need for a more practice-oriented publication related to environmental engineering. The International Water Association recently launched a new online journal titled *Water Practice & Technology*, and the Water Environment Federation plans to start a new journal titled *Water Practice.* We intend that *Environmental Engineer: Applied Research and Practice* focus will transcend water to include multi-media and professional issues as well.

The Editorial Board encourages submission of papers focused on practical research and useful case studies related to environmental engineering. Practical "know-how" reports, interesting designs, and evaluations of engineering processes and systems are examples of appropriate topics. 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: C. Robert Baillod, Editor, *Environmental Engineer: Applied Research and Practice*, baillod@mtu.edu. The Editorial Board strives for prompt review and publication.

Editorial Board:

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.

C. Robert Baillod, Ph.D., P.E., BCEE
Editor e-mail: baillod@mtu.edu
Yolanda Moulden
Assistant Editor email: YMoulden@aaee.net

For questions or hard copy submission, please contact:
Yolanda Moulden, Assistant Editor
AAEE
130 Holiday Court, Suite 100
Annapolis, MD 21401
ATTN: Yolanda Moulden
(410) 266-3311
(410) 266-7653 (Fax)

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.

COPYRIGHT

Copyright on all published articles will be held by AAEE.

AAEE's copyright protects articles or works of authors published in the journal from unauthorized duplication. It does not protect any products, devices, equipment, or procedures described therein from unauthorized use by others.

TREATMENT OPTIONS FOR REMEDIATION OF 1,4-DIOXANE IN GROUNDWATER

William DiGuiseppi, P.G. [1] and Caroline Whitesides, P.G. [2]

ABSTRACT

The solvent stabilizer 1,4-dioxane has emerged in the environmental engineering arena as an unexpected and recalcitrant groundwater contaminant at many sites across the US. Decreases in the analytical detection limit in water have revealed the presence of this contaminant in sites where no 1,4-dioxane was identified during earlier, higher MDL sampling events. Toxicological studies suggest that 1,4-dioxane may be harmful, and it has been designated as a probable human carcinogen. However, the toxicity of 1,4-dioxane is in dispute and the United States Environmental Protection Agency is in the process of reviewing the toxicological information on 1,4-dioxane towards potentially revising the oral cancer slope factor and associated risk screening levels. Chemical characteristics of 1,4-Dioxane, such as high mobility, enable it to migrate much further than the solvent from which it likely originated. This has challenged remedial project managers to redesign treatment systems and monitoring networks to accommodate widespread contamination. This paper summarizes the fate and transport characteristics of 1,4-dioxane and presents current thinking in the environmental engineering community related to remedial technologies that may be applicable to groundwater treatment. At this point in time, *ex-situ* remediation has been performed at numerous sites for 1,4-dioxane, but no full scale *in-situ* remediation projects have been completed.

INTRODUCTION

1,4-Dioxane was historically used as a stabilizer in chlorinated solvents, mainly for 1,1,1-trichloroethane (TCA) (United States Environmental Protection Agency [U.S. EPA], 2006). The solvent TCA is regulated as a hazardous waste and was the primary focus of contaminant investigation programs, however, 1,4-dioxane is not one of the U.S. EPA's priority pollutants and does not have a maximum contaminant level (MCL) for drinking water. Consequently it has not been routinely analyzed in groundwater at solvent release sites or included in the cleanup objectives of regulatory orders (Mohr, 2001). Even sites where full Appendix VIII (40 Code of Federal Regulations Part 261) analyses were run in the 1980s or 1990s may not have identified lower levels of 1,4-dioxane because detection limits at the time were higher than they are now (e.g., 100's of ug/L). Because many 1,4-dioxane plumes are below 100 µg/L, this chemical would have been missed during characterization and remediation. Given the present uncertainty regarding the toxicology for 1,4-dioxane, it is not clear whether values as high as 100 ug/L would be harmful.

CHEMICAL BACKGROUND

1,4-Dioxane (also known as dioxane, p-dioxane, diethylene ether, diethylene dioxide, and glycol ethylene ether (U.S. EPA, 2007a) is currently used as a solvent in chemicals (paints, lacquers, varnishes, varnish removers, wood pulping, fats, oils, waxes, and resins) and as a laboratory reagent. It may also be found at trace levels in cosmetic products such as shampoos and bath preparation, and in detergents (Agency for Toxic Substances and Disease Registry, 2007). However, it should not be confused with dioxin, an entirely different and well-known class of chemical compounds.

Stabilizers such as 1,4-dioxane were added to solvents to serve as antioxidants, acid inhibitors, and metal stabilizers, which inhibit reactions that otherwise lead to the deterioration and ultimate breakdown of the solvent, diminishing or preventing the proper solvent performance in the intended application (Mohr, 2004). Historically, 1,4-dioxane has been included with 1,1,1-TCA in mixtures at 2 to 8 percent by volume (Mohr, 2001).

The chemical structure of 1,4-dioxane consists of a cyclic organic compound with two opposed ether linkages. Its two oxygen atoms make it hydrophilic and infinitely soluble (miscible) in water. The chemical properties of 1,4-dioxane and a 2-dimensional structure diagram are shown in Table 1.

The hydrophilic nature of 1,4-dioxane makes it fully miscible in water. Because of its high solubility, 1,4-dioxane is very mobile and only weakly retarded by sorption during transport. 1,4-Dioxane's solubility in water and moderate vapor pressure may result in potential volatilization, but transfer from water to air is negligible. 1,4-Dioxane is not typically degraded by indigenous soil microorganisms under ambient conditions. Due to its infinite solubility, resistance to biodegradation under natural conditions, low Henry's Law constant, and low affinity for soil organic matter, 1,4-dioxane is extremely mobile, moving far ahead of the volatile organic compound (VOC) plumes in which it is found (Mohr, 2004).

RISKS AND REGULATIONS

Because 1,4-dioxane is among the most mobile and persistent organic compounds released at sites, attention to the risk associated with this compound is warranted. Little data are available related to human exposure to 1,4-dioxane, and no adequate epidemiological data are available to assess the carcinogenicity of 1,4-dioxane to humans (Mohr, 2001). International Agency for Research on Cancer (IARC) classifies 1,4-dioxane as Group 2B, possible human carcinogen based on lack of human evidence, sufficient evidence in animals, and inadequate evidence in short-term tests. The U.S. EPA classifies 1,4-dioxane as B2, a probable human carcinogen, based on the induction of nasal cavity and liver carcinomas in multiple strains of rats, liver carcinomas in mice, and gall bladder carcinomas in guinea pigs (U.S. EPA, 1995). These data show that, via the oral route, 1,4-dioxane targets the liver and nasal cavity in rats, resulting in a cancer slope factor of 1.1×10^{-2} milligrams/kilogram/day (Mohr, 2001). The relevancy of nasal cavity tumors to human exposure is questionable, since rats supplied with water from bottle tubes were observed to aspirate water directly into their nasal passages, a route not replicated in human ingestion. Damage to the liver was only observed at very high doses exceeding the rat's capacity to expel 1,4-dioxane. Other studies suggest that the current cancer slope factor used by the U.S. EPA significantly overestimates the potential cancer risk, and that other modeling studies may provide more accurate means for estimating potential human cancer risks (Stickney et al., 2003). Due to uncertainties regarding the toxicological studies used to derive the cancer slope factor, the severity of impact from 1,4-dioxane is currently being reassessed under the U.S. EPA's Integrated Risk Information System (IRIS) (U.S. EPA, 2006); however, the results are not anticipated to be available to the public until October 2008 (U.S. EPA, 2007b).

Based on the existing risk information and because analytical methods have improved to allow detection of 1,4-dioxane at levels similar to other VOCs, some states have now established enforceable cleanup goals. Colorado was the first state to establish an enforceable standard of 6.1 µg/L for 1,4-dioxane in groundwater after March 2005 and a 3.2-µg/L limit after March 2010 (Colorado Department of Public Health and Environment, 2005). The present standard was derived based on toxicological information presented in IRIS, however, in response to public concerns, as well as the uncertainty in the toxicological research, CDPHE conservatively included the stepped down criteria in the future. It is not clear whether future changes in IRIS will be reflected in CDPHE's standards. In addition, three U.S. EPA regions and 13 other states have developed non-enforceable guidance criteria for characterizing and remediating 1,4-dioxane in soil and groundwater. Soil exposure standards range from 23 mg/kg in Florida for residential exposures to 29,000 mg/kg in Texas for industrial exposures. Groundwater standards range from 3 ug/L in California to 350 ug/L for industrial usage in Michigan (U.S. EPA, 2006).

TECHNIQUES FOR 1,4-DIOXANE REMEDIATION IN GROUNDWATER

Air Stripping

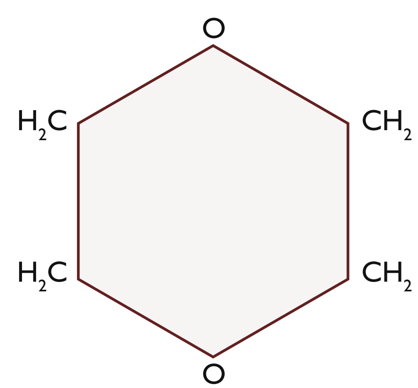
Air stripping is a typical *ex-situ* treatment for common volatile organic contaminants in groundwater, such as benzene and trichloroethene. Because 1,4-dioxane is a VOC, it is reasonable to evaluate air stripping as a potential remedial technology. However, although 1,4-dioxane has a high vapor pressure suggesting it is highly volatile, it is also highly soluble. Therefore, 1,4-dioxane is very difficult to remove from water. To evaluate 1,4-dioxane's stripping potential, air flow was optimized through a cascading water column in a 40-foot-tall packed vertical stripping tower at an ongoing groundwater remediation site. In a series of six different optimization scenarios, influent 1,4-dioxane concentrations ranged from 7.6 to 11.1 µg/L and effluent levels ranged from 7.0 to 10.0 µg/L, using air:water ratios between 183 and 291 (Earth Tech, Inc., 2004). The maximum possible removal rate approached 10 percent, which was not sufficient to meet potential cleanup standards. While this testing indicated a small decline in concentrations, the results were not repeatable or reliable enough to consider this a viable option for 1,4-dioxane remediation. A more focused and comprehensive mass transfer approach, combining air stripping with air sparging, soil vapor extraction, enhanced bioremediation, and dynamic subsurface groundwater circulation, has been demonstrated to be effective in specific circumstances (Odah et al., 2005). The in-well technology has been utilized at several sites to reduce high concentrations of 1,4-dioxane by more than 90 percent, from 28,000 µg/L to 2,400 µg/L in one case. It is not clear whether this technology would be effective for ultimately reducing levels below the groundwater standards presented above or for reductions from lower starting concentrations typical of most sites.

Sorption

Sorption is a commonly applied *ex-situ* technology for treatment of organic contaminants in extracted groundwater. However, 1,4-dioxane has a low partitioning coefficient between soil organic matter and dissolved 1,4-dioxane in water (log K_{oc}) of 0.54, suggesting that it would not preferentially sorb to soil particles or other sorption media. Bench-scale treatability testing was conducted to evaluate the effectiveness of removal of 1,4-dioxane from groundwater using a variety of sorbants, including Activated

TABLE 1 Chemical Properties and Structure of 1,4-Dioxane

CAS RN	123-91-1
Molecular weight	88.12
Molecular formula	$C_4H_8O_2$
Water Solubility (A20ºC)	Miscible
Boiling Point (ºC at 760 mm Hg)	101.32
Melting Point (ºC at 760 mm Hg)	11.8
Vapor Pressure (mm Mg @25ºC)	38.09
Vapor Density	3.03
Henry's Constant (atm-m³/mol)	4.80×10^{-6}
Log K_{OW}	0.43
Log K_{OC}	0.54
Specific Gravity (@20ºC)	1.03



1,4-dioxane

Sources: CHEMFATE, 2007; Mohr, 2001
Notes: atm = atmosphere, mm Hg = millimeters of mercury, m = meter, mol = mole, ºC = degrees Celsius

Tri-Base pelletized carbon, which contains three different types of carbon in a single pellet, surfactant modified zeolites (SMZ), SMZ with zero valent iron (SMZ/ZVI), and a proprietary macro-porous polymer manufactured by Akzo Nobel (Earth Tech, Inc., 2004). The study involved shaker tests of each medium at a range of medium:water ratios from 1:2 to 1:10,000 and at 1,4-dioxane concentrations from approximately 40 to 70 µg/L. The treatability testing demonstrated that the two zeolite formulations and the macro-porous polymer were ineffective for removal of 1,4-dioxane. Only the Activated Tri-Base carbon, manufactured by Hiatt Distributors Limited, showed effective 1,4-dioxane adsorption, but only at medium: water ratios greater than 1:20. Based on the Freundlich isotherm, a partitioning coefficient (K_d) of 264.7 L/kg was derived, which yielded a carbon usage rate for the project of 1,479 tons per year. This quantity was far in excess of what would be cost effective or logistically achievable for this site. Research by Johns et al. (1998) looked into the sorption characteristics of granular activated carbon (GAC) sorbants derived from a variety of organic material sources. The GAC made from crushed pecan and walnut shells proved to be the most effective at removal of 1,4-dioxane from an organic chemical mixture with up to 50 percent removal rates. In addition, they identified steam activation as producing a more effective adsorbent than CO_2 activation of the nutshell carbon products. These studies demonstrate that sorption may be viable technology under the right site conditions (i.e., low aquifer yield, low concentrations) and with the right sorbant.

Monitored Natural Attenuation (MNA)

Monitored natural attenuation (MNA) has been accepted as a remedial approach for many VOCs, including chlorinated solvents and petroleum contaminants, such as trichloroethene (TCE) and benzene, toluene, ethylbenzene and xylenes (BTEX), respectively. Documented attenuation mechanisms typically include biodegradation, sorption, dilution, dispersion, volatilization and chemical reactions with soil and groundwater. Natural attenuation of 1,4-dioxane has not been studied extensively, but it would be reasonable to consider some of the above mechanisms as applicable to 1,4-dioxane. Due to its high solubility and low K_{oc}, volatilization and sorption are not expected to play a role in attenuation. Dispersion and dilution are important attenuation factors for 1,4-dioxane because it is miscible in water. Biodegradation has also been demonstrated under certain conditions and may be a factor at specific sites. Chiang et al. (2006) conducted solute fate and transport modeling using a numerical flow model to simulate observed 1,4-dioxane plume migration characteristics at an industrial site in the southeast United States. 1,4-Dioxane degradation half-lives were initially estimated based on literature reviews and a kinetic study of historical chemical data collected since the early 1990s, and then calibrated to present conditions. Several scenarios, including various degradation scenarios and a non-degradation scenario, were tested. The findings of the modeling indicated that the non-destructive scenario underestimated the decay rate observed in the field. According to Chiang et al.: "… the numerical simulation of 1,4-dioxane with a 7-year degradation half-life (corresponding to a degradation rate of 0.099 $year^{-1}$) better simulated the field measurements." This modeling study was used to support the selection of MNA, which was approved by the state agency as the proposed groundwater remedy for the site.

Phytoremediation

Phytoremediation has been demonstrated to address VOCs in groundwater, such as TCE, through mass transfer of the contaminant up through the root system and transpiration from the leaves of several different kinds of plants, as well as potential degradation of the chemicals in the root zone through enzymatic action. Phytoremediation of 1,4-dioxane was evaluated at the bench scale by Aitchison et al. (1997) using hybrid poplar cuttings. Plant uptake and destruction of contaminants in the root zone were both evaluated. An average of 54 percent of the 1,4-dioxane mass was removed from the plant reactors within 9 days. The distribution of carbon from ^{14}C labeled 1,4-dioxane indicated that the majority (77 percent) of the 1,4-dioxane removed from the reactors was volatilized, and the bulk of the remainder was present in the stem. Once released to the atmosphere, photochemically produced hydroxyl radicals can degrade 1,4-dioxane with a half-life of between 6.7 and 9.6 hours (U.S. EPA, 1995). Kelley et al. (1997) evaluated microcosm studies of *Actinomycetes* CB 1190 to enhance bioremediation of 1,4-dioxane in the poplar (*Populus sp.*) rhizosphere. The bacteria were cultured in a 0.1% tetrahydrofuran (THF) solution by Dr. Rebecca Parales at the University of Iowa. Testing results indicated complete degradation of 100,000 µg/L 1,4-dioxane within 45 days. This destruction suggests that hybrid poplars, which exhibit rapid uptake of 1,4-dioxane, coupled with bioaugmentation of the root zone, could be a viable remedial technology under the right conditions. Documented field application of phytoremediation of 1,4-dioxane is limited to one study by Chiang et al. (2007). The phytoremediation system was installed in an area of approximately 8,000 sq. ft. to address a groundwater seep with the potential to impact surface water. Over 100 poplar trees were planted in 12 rows perpendicular to the groundwater flow direction. Later, an additional 100 hybrid poplar cuttings were planted between the trees to increase immediate water uptake capacity. Seep sample locations were not able to be sampled in the summer of 2006 because they were dry, which was interpreted to be a direct result of the dewatering (i.e., water uptake) capacity of the trees. Limitations of phytoremediation, regardless of the target compound, include depth to water and variable growing seasons.

Bioremediation

Bioremediation of organic contaminants has been demonstrated to be effective at many project sites, such that it is almost considered a presumptive remedy for some contaminants, such as chlorinated organics. Laboratory research and field pilot studies have identified several different types of bacteria that are effective at either utilizing the 1,4-dioxane as a carbon and energy source or co-metabolically degrading 1,4-dioxane while consuming another carbon source. Parales et al. (1994) isolated a bacteria of the family *Pseudonocardiacae* from a sludge sample contaminated with THF that was capable of degrading 1,4-dioxane directly. These bacteria used 1,4-dioxane as the sole source of carbon, but only when it had been isolated from the THF-contaminated sludge. Direct growth of the bacteria using only 1,4-dioxane was unsuccessful. Experimental evidence indicated that more than 50 percent of the carbon in the dioxane was mineralized to CO_2. Additional biodegradation evidence comes from a fixed film bioreactor that was bench tested, then field tested at the Lowry

Landfill, in Denver Colorado, on 1,4-dioxane levels of 8000 to 12,000 µg/L in groundwater (Mohr, 2004; Shangraw, 2006). The field pilot system was operated at less than 1 gpm at a controlled influent temperature of 15-25 degrees Celsius (°C) to allow direct biological destruction of the 1,4-dioxane. The site groundwater, from a former municipal landfill, was fortuitously contaminated with high levels (20,000-30,000 µg/L) of THF. The study confirmed earlier findings that the THF was necessary for the growth of the bacteria. Co-metabolic bioremediation of 1,4-dioxane has been demonstrated to be effective with several gasotrophic bacteria, including aerobic propanotrophs (Findlay et al., 2007) that destroy the 1,4-dioxane using the enzyme systems developed to utilize oxygen. In related research, the cultured bacteria (SL-D), as well as naturally occurring bacteria, can be stimulated with propane, and studies have shown that the microorganisms only destroy the dioxane after most of the propane has been consumed. The bacteria have been shown to degrade 100 percent of 1,4-dioxane, up to 10,000 µg/L, within 12 hours (Fam et al., 2005). All *in-situ* methods are subject to limitations in getting the amendment to the contaminated zones, and the groundwater chemistry alteration (e.g., anaerobic versus aerobic conditions) created to stimulate biological activity can cause naturally occurring elements to be mobilized in exceedance of drinking water standards. These changed conditions typically revert to natural conditions once the enhancing amendments are consumed.

Chemical Oxidation

Chemical oxidation is an effective contaminant destruction method regularly applied to organic compounds such as chlorinated VOCs. Oxidation systems that have been proven effective on a variety of organic compounds in bench and field applications include ultraviolet (UV) light, ozone, hydrogen peroxide, sodium permanganate, potassium permanganate, Fenton's Reagent (H_2O_2+ferrous iron), UV + peroxide, ozone + peroxide, and sodium persulfate. Table 2 presents the oxidation potentials for some common oxidizers.

For 1,4-dioxane, the cyclic ether compound is more resistant to chemical breakdown and requires stronger oxidizers with an oxidation potential of greater than about 2.0 electron volts (eV). Of the oxidants listed above, only Fenton's Reagent (H_2O_2 + ferrous iron), UV + peroxide, ozone + peroxide, and sodium persulfate have a sufficiently high oxidation potential (eV) to reliably destroy 1,4-dioxane. The first three of these methods create the hydroxyl radical (OH^-), which has an oxidation potential of 2.7 eV and is identified as one of the strongest oxidizers available. Sodium persulfate has an oxidation potential of 2.1 eV, which is marginally capable, but when activated with alkaline solutions (sodium or calcium hydroxide) or steam, produces the sulfate radical (SO_4^-), which has an oxidation potential of 2.6 eV. These higher-level oxidation methods are collectively referred to as advanced oxidation technologies and are proven technologies in *ex-situ* applications. Ozone-peroxide destruction of 1,4-dioxane in *ex-situ* applications is well documented (Bowman and Mohr, 2004; Mohr, 2004; Suh and Mohseni, 2004) as is UV peroxide (Kim et al., 2006; USACE/NAVFAC/AFCESA, 2006; Brode et al., 2005). Schrier et al. (2006) demonstrated effective reduction in 1,4-dioxane concentrations in bench-scale studies using ozone and a combination of ozone and hydrogen peroxide. Ferrous iron (2,000 µg/L), chelated iron (2,000 µg/L iron), and alkalinity (1,000,000 µg/L as $CaCO_3$) were added to deionized water to simulate field conditions that might be present. These additives reacted with the ozone to provide nearly as effective treatment as the ozone plus peroxide. This is a significant finding because it would eliminate the problems associated with getting the right mixture of two injected agents. While these advanced oxidation technologies can rapidly destroy 1,4-dioxane under *ex-situ* or controlled laboratory conditions, the inherent difficulty for *in-situ* applications is getting the treatment amendment to the contaminant location. For some of the high-powered oxidizers, such as the hydroxyl radical, the very short half-life (hours) makes forced migration of the treatment materials difficult or impossible. For many oxidation approaches, the issue is further complicated by the requirement to mix two reagents, for example $H_2O_2 + O_3$, to achieve the high oxidation potential. In aquifer conditions, highly heterogeneous geological conditions may make accurate mixing of these amendments difficult. An additional consideration for application of oxidizers in general, is the possibility of mobilizing other contaminants, such as hexavalent chromium, which can be created by oxidizing trivalent chromium in the soil. Lastly, bromate, which has an MCL of 100 µg/L, may be formed through the oxidation of bromide, which is common in natural groundwater. In carefully controlled *ex-situ* applications, bromate production can be minimized or eliminated by optimizing the proportions of various oxidizers, but *in-situ* applications are much harder to regulate and bromate production may be an issue. *In-situ* application of chemical oxidation for 1,4-dioxane treatment has not been documented at more than the field pilot scale.

TABLE 2 Oxidant Strengths

Chemical Species	Standard Oxidation Potential (volts)	Relative Strength (chlorine = 1)
Hydroxyl radical (OH^-)*	2.8	2.0
Sulfate radical (SO_4^-)	2.5	1.8
Ozone	2.1	1.5
Sodium persulfate	2.0	1.5
Hydrogen peroxide	1.8	1.3
Permanganate (Na/K)	1.7	1.2
Chlorine	1.4	1.0
Oxygen	1.2	0.9
Superoxide ion (O^-)*	-2.4	-1.8

*These radicals can be formed when ozone and H_2O_2 decompose.
Source: Siegrist et al. 2001

SUMMARY AND CONCLUSIONS

The solvent stabilizer 1,4 dioxane has emerged recently as a groundwater contaminant of concern at a number of sites across the U.S., and state and federal regulatory agencies are focusing considerable attention on defining the magnitude and extent, and possible impact, of 1,4-dioxane sources and plumes, as well as identifying applicable remedial technologies. The chemical characteristics that make 1,4-dioxane particularly troublesome, from a cleanup standpoint, are its miscibility in water, low sorption characteristics, and minimal biodegradability, making it highly mobile and environmentally persistent in groundwater.

As of the publication of this article, the only successfully demonstrated full-scale technologies for 1,4-dioxane remediation are groundwater extraction and ex situ treatment using controlled bioreactors or advanced oxidation techniques (e.g., UV+ peroxide, ozone + peroxide, etc.). Adsorption methods using specialty carbon materials indicate some level of removal that might be sufficient, but the selection of the carbon type appears to play a large role. Air stripping has been shown to be ineffective in the traditional sense, but may have applications using in-well stripping, sparging and aerobic biostimulation techniques.

Many in situ approaches have been demonstrated in bench-scale and field-scale treatability tests and show promise for full-scale application. Among these, the most promising for typical 1,4-dioxane sites with concentrations in the hundreds of ug/L, appear to be *in-situ* chemical oxidation and bioremediation. Typical limitations of any in situ method, such as delivering the oxidant to the contaminant, are exacerbated by the reactivity and short half life of the strong oxidizers required. Bioremediation methods appear to require non-native microorganisms, as well as nutrients, to achieve optimal conditions for the destruction of the 1,4-dioxane. Research programs in industry and academia are actively seeking additional chemical and biological solutions to this vexing problem.

ABOUT THE AUTHORS

1. Project Manager, Senior Hydrogeologist, and Geosciences Department Manager, Earth Tech, Inc., 5575 DTC Parkway, Suite 200, Greenwood Village, Colorado 80111
2. Project Manager and Project Hydrogeologist, Earth Tech, Inc., 5575 DTC Parkway, Suite 200, Greenwood Village, Colorado 80111

REFERENCES

Agency for Toxic Substances and Disease Registry. 2007. "ToxFAQs for 1,4-Dioxane" (July 2006). Accessed on the web on February 4, 2007, at http://www.atsdr.cdc.gov/tfacts187.html.

Aitchison, E.W., J.L. Schnoor, S.L. Kelley, and P.J.J. Alvarez. 1997. "Phytoremediation of 1,4-Dioxane by Hybrid Poplars." Kansas State University, 1997 Conference on Hazardous Waste Research.

Bowman, R.H., and T.K.G. Mohr. "AOP Treats Dioxane-contaminated Ground Water." Presented in EPA's *Technology News and Trends*, March 2004.

Brode, J., F. Fotouhi, and S. Kolon. 2005. "Ultraviolet and Hydrogen Peroxide Treatment Removes 1,4-Dioxane from Multiple Aquifers." Presented in EPA's *Technology News ands Trends*, March 2004.

CHEMFATE. 2007. Database listing for 1,4-dioxane. Accessed on February 16, 2007, at http://www.syrres.com/esc/chemfate.html.

Chiang, D., Y. Zhang, E, Glover, J. Harrigan, and D. Woodward. 2006. "1,4-Dioxane Solute Transport Modeling in Support of Natural Attenuation Determination." Proceedings of the Fifth International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California, May 22-25, 2006.

Chiang, D., E. Glover, B. Dahlgren, D. Woodward, and E.W. Aitchison. 2007. "Phytoremediation of 1,4-Dioxane for Groundwater Seep Remediation." Abstract submitted to Battelle's Ninth International In Situ and On-Site Bioremediation Symposium, Baltimore, Maryland. May 7-10, 2007.

Code of Federal Regulations, Title 40, Part 261, Appendix VIII.

Colorado Department of Public Health and Environment, Water Quality Control Commission. 2005. The Basic Standards for Groundwater. 5 Code of Colorado Regulations, Regulation No. 41.

Earth Tech, Inc. 2004. *Technology Evaluation for Treatment of 1,4-Dioxane in Groundwater*. Prepared for the Air Force Center for Environmental Excellence. December 2004.

Fam, S.A., S. Fogel, and M. Findlay. 2005. "Rapid Degradation of 1,4-Dioxane using a Cultured Propanotroph." Proceedings of the International In Situ and On-Site Bioremediation Symposium, Baltimore, Maryland, June 6-9, 2005.

Findlay, M., D. Smoler, and S. Fogel. 2007. "Dioxane-degrading Propanotrophs for *In Situ* Remediation." Abstract for Battelle 2007 in Baltimore.

Johns, M.M., W.E. Marshall, and C.A. Toles. 1998. "Agricultural By-products as Granular Activated Carbons for Adsorbing Dissolved Metals and Organics." *J. Chem. Technol. Biotechnical.* 71: 131-140.

Kelley, S.L., P.J.J. Alvarez, E.W. Aitchison, and J.L. Schnoor, 1997. "Bioaugmentation with Actinomycetes CB1190 to Enhance Phytoremediation of 1.4-Dioxane." Kansas State University, 1997 Conference on Hazardous Waste Research.

Kim, C.G., H.J. Seo, and B.R. Lee. 2006. "Decomposition of 1,4-Dioxane by Advanced Oxidation and Biochemical Process." *J. Environ. Sci. Health A Tox Hazard Subst Environ Eng*. 2006;41(4):599-611.

Mohr, T.K.G. 2001. "Solvent Stabilizers White Paper." Prepublication Copy. Santa Clara Valley Water District of California. San Jose, California. June 14, 2001.

Mohr, T.K.G. 2004. "GRA's 1,4-Dioxane Conference Profiles National Challenge of Emerging and Unregulated Contaminants." *Hydrovisions, Groundwater Resources Association of California*, Volume 13, No. 1, Spring 2004.

Odah, M.M., R. Powell, and D.J. Riddle. 2005. "ART In-well Technology Proves Effective in Treating 1,4-Dioxane Contamination." *Remediation Journal*, 15(3): 51-64. Published online 15 Jun 2005.

Parales, R.E., J.E. Adamus, N. White, and H.D. May. 1994. "Degradation of 1,4-Dioxane by an *Actinomycete* in Pure Culture." *Applied and Environmental Microbiology*, 60(12): 4527-4530. December.

Schreier, C.G., V.M. Sadeghi, D.J. Gruber, J. Brackin, M. Simon, and E. Yunker. "In-Situ Oxidation of 1,4-Dioxane." Proceedings of the Fifth International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California, May 22-25, 2006.

Shangraw, T., 2006. personal communication to Bill DiGuiseppi, Earth Tech, Inc., on June 15, 2006.

Siegrist, R. L., M. A. Urynowicz, O. R. West, M. L. Crimi, and K. S. Lowe (eds.). 2001. *Guidance for In Situ Chemical Oxidation at Contaminated Sites: Technol-*

ogy Overview with a Focus on Permanganate Systems. Columbus, Ohio: Battelle Press.
Stickney, J.A., S.L. Sager, J.R. Clarkson, L.A. Smith, B.J. Locey, M.J. Bock, R. Hartung, and S.F. Olp. 2003. "An Updated Evaluation of the Carcinogenic Potential of 1,4-Dioxane." *Regulatory Toxicology and Pharmacology*. 38: 183-195.
Suh J.H., and M. Mohseni. 2004. "A Study on the Relationship Between Biodegradability Enhancement and Oxidation of 1,4-Dioxane Using Ozone and Hydrogen Peroxide." *Water Research*, May 2004, 38(10): 2596-604.
U.S. Environmental Protection Agency, 1995. *OPPT Chemical Fact Sheets - 1,4-Dioxane Fact Sheet: Support Document (CAS No. 123-9-1)*. United States Environmental Protection Agency, Pollution Prevention and Toxics. EPA 749-F-95-010a. February.
U.S. Environmental Protection Agency. 2006. *Treatment Technologies for 1,4-Dioxane: Fundamentals and Field Applications*. Office of Solid Waste and Emergency Response. EPA-542-R-06-009. December.
U.S. Environmental Protection Agency. 2007a. *Substance Registry System* accessed at http://iaspub.epa.gov/srs/srs_proc_qry.navigate?P_SUB_ID=33241 on February 4, 2007.
U.S. Environmental Protection Agency. 2007b. *Integrated Risk Information System Detailed Tracking Report for IRIS Chemical Assessment* accessed at http://cfpub.epa.gov/iristrac/index.cfm?fuseaction=viewChemical.showChemical&sw_id=1025 on February 12, 2007.
USACE/NAVFAC/AFCESA. 2006. *Advanced Oxidation Processes (AOP)*. Unified Facilities Guide Specification UFGS-44 44 53, 41 pp, 2006.

NITROGEN SOURCES AND CONSUMPTION IN BREWERY WASTEWATER TREATMENT

Julie E. Smith, P.E.[1] and Linda A. Figueroa, Ph.D., P.E.[2]

ABSTRACT

Because brewery wastewater is limited in nitrogen, biological treatment by an activated sludge process requires supplemental ammonia for a healthy biomass with good settling properties. Control of effluent ammonia while still meeting biomass nutritional requirements is an operational challenge. Nitrogen mass balances of the Coors Golden Brewery wastewater based on ammonia indicate that the biomass is generally nitrogen deficient, with total organic carbon:nitrogen ratios ranging from 16:1 to 103:1, significantly higher than the optimum 10:1. At the same time, total Kjeldahl nitrogen of the sludge is about 10% nitrogen by weight, indicating adequate nitrogen levels for healthy metabolism. Total and soluble Kjeldahl nitrogen of the wastewater show significant levels of organic nitrogen, which appears to be metabolized by the biomass. The Simulation of Single Sludge Processes (SSSP) software was used to improve understanding of nitrogen sources and utilization in the pure oxygen activated sludge process, and thus improve control of ammonia supplemental feeding and effluent quality. Various operating strategies were evaluated, such as step feed, adjustment of nitrogen feed and varying sludge age. Brewery wastewater streams from malting, packaging, brewing, fermenting, and yeast drying, were characterized and applied to the model to determine differences in supplemental nitrogen needs.

INTRODUCTION

Control of effluent ammonia in brewery wastewater while still meeting the nutritional requirements of the biomass in an activated sludge process is an operational challenge. Because brewery wastewater is limited in nitrogen, supplemental ammonia is added to optimize biomass metabolism. Past operational experience has shown that biomass settling is adversely affected when nitrogen is depleted. At the Coors Golden Brewery, ammonia feed is controlled based on ammonia analyses of grab samples upstream and downstream of aeration basins several times a day. This strategy is not always effective and there are times when the effluent ammonia concentrations are unexpectedly high. Ammonia in the downstream (mixed liquor) sample is sometimes much higher than expected, at times when the upstream ammonia does not appear to be in excess. At other times, all ammonia is consumed, leaving no residual and possibly stressing the biomass. The challenge with brewery wastewater, then, is as much an issue of ammonia supplement control as ammonia removal and discharge compliance. The purpose of this project was to model ammonia removal in the Coors Golden Brewery Process Waste Treatment Plant (PWTP) to identify potential monitoring, operational, and control procedures to minimize effluent ammonia.

Mass balances of ammonia-nitrogen (NH_3-N) and carbon around the aeration basins at the Coors PWTP have proved confusing. Biomass requires about 1 part nitrogen (N) to 10 parts carbon (C) for healthy metabolism (Rittmann 2001). Yet, when all sources of NH_3-N are mass balanced, the Coors PWTP C:N ratio is typically much higher, suggesting the biomass is often nitrogen-deficient. For example, in April 2004, an average total organic carbon (TOC):NH_3-N ratio of 48:1 in the primary effluent was observed, with a high of 103:1 and a low of 16:1. The month of April was a typical month in terms of C:N ratio. However, total Kjeldahl nitrogen (TKN) of biomass shows the nitrogen content of the sludge to average about 10% by weight, well within the normal range. One possible explanation was that NH_3-N does not represent all of the total available nitrogen and that other sources of available nitrogen may be present in the brewery waste. A better understanding of nitrogen availability and utilization was needed because nutrient deficiencies were a suspected cause of sludge settling problems. It was also felt that a better understanding of nitrogen might allow better control of ammonia supplementation, with concurrent chemical cost savings.

Brewery wastewater contains a variety of substrates, several of which provide nitrogen as organically bound particulate or soluble nitrogen. Particulate forms include grain, rice and yeast, and soluble forms include wort, extract, trub, and beer waste. Trub, in particular, is 20 – 35% protein (Hough 1994) and therefore contributes significant nitrogen to the waste stream. For the organic nitrogen to become available to the biomass, the nitrogen from the soluble sources must undergo ammonification in the aeration system, a process whereby organically bound nitrogen is converted to ammonia via microbial action. It has been questioned whether this process occurs to a sufficient extent to provide significant NH_3-N during the treatment process (Jenkins 2004).

Table 1 compares key parameters of example substrates present in brewery waste that can either provide or consume ammonia as a byproduct of metabolism. A net consumption of NH_3-N in the table indicates a need for supplemental NH_3-N for that substrate, while a "negative consumption" indicates production of NH_3-N during substrate utilization. These relationships were developed stoichiometrically using the methods described by Rittmann and McCarty (2001). Biomass processes the substrates that provide the most energy; therefore, the reactions that provide the largest free energy changes are most likely to take place preferentially in the treatment system. The most energy is gained from metabolism of glucose, and metabolism of this substrate consumes about 0.124 gram (g) of ammonia nitrogen per g of biomass synthesized. NH_3-N is actually released during metabolism of protein and this gain to the system is equal to the uptake of NH_3-N during processing of glucose. Given that some substrates release NH_3-N while others utilize it suggests that the substrate mix on a given day can strongly affect ammonia supplementation. Further, because brewery operations are batch processes, it is likely that the need for supplementation can vary significantly during the day, depending not only on the organic concentrations in the waste, but on which processes are sending waste to the waste treatment plant.

The theoretical TOC to nitrogen ratio is about 6:1 when glucose is the sole substrate, which means that for this substrate about 1 part of ammonia nitrogen should be available for every 6 parts of substrate provided as organic carbon. Theoretical cell yields are similar for all five substrates in the table, between 0.4 and 0.5 g of cells for each gram of chemical oxygen demand (COD) as substrate provided.

The first three substrates in Table 1 are similar in that they are simple short-chain organic molecules that contain only carbon and oxygen, with no nitrogen, so the nitrogen demand is higher for cell metabolism. In reality, brewery waste is a complex blend of substrates, some of which contains organically bound nitrogen. The last two substrates are generally accepted formulas for complex wastes (Rittmann 2001). General complex organic matter consumes relatively little free NH_3-N during metabolism, because it contains a significant amount of nitrogen. This leads to a relatively high TOC:N consumption ratio of 22.6:1, which is significantly higher than the accepted required TOC:N ratio of 10:1 for activated sludge systems. The generic protein in Table 1 shows an important difference from the other substrates, because it actually generates ammonia nitrogen, as indicated by the negative sign, during cell synthesis. The ammonia generation during metabolism of protein is similar numerically to that consumed during metabolism of the first three substrates. This suggests protein can have a strong effect on consumption and demand of nitrogen. This is important, because some brewery waste contains high levels of protein.

Ammonia is also released in the aeration system from the return activated sludge (RAS) as a result of endogeny and cell decay. A mass balance indicates the nitrogen production for cell decay is the same as that for protein, about 0.124 g NH_3-N per g of cell decayed.

Table 1 Comparison of theoretical ammonia consumption, cell yield and energy gain during cell synthesis and metabolism of substrates present in brewery waste.

Substrate	Free Energy KJ/e-eq	Yield g Cells/g COD	NH_3-N Consumption g N/g cells	TOC:N Consumption Ratio g TOC/g N
Glucose	-120.1	0.508	0.124	6.0:1
Ethanol	-109.9	0.450	0.123	4.4:1
VFA (Acetate)	-106.1	0.417	0.124	7.1:1
$C_8H_{17}O_3N$ (general complex organic matter) (Rittman 2001)	NA	0.459	0.029	22.6:1
$C_{16}H_{24}O_5N_4$ (general protein) (Rittman 2001)	NA	0.459	-0.124	--

METHODOLOGY

The goal of this work was to gain a better understanding of nitrogen sources in the complex blend of process waste streams from the brewery as a first step toward more efficient management of supplemental nitrogen feed. This process began with complete analysis of separate and mixed brewery waste streams, including TKN, soluble Kjeldahl nitrogen (SKN), TOC, dissolved organic carbon (DOC), total suspended solids (TSS) and volatile suspended solids (VSS). The Kjeldahl method as described in "Standard Methods", 19th Edition, was used to determine TKN and SKN. Duplicates were run for all samples, with rpd values averaging 6.25% and ranging from 0.19 to 20% for duplicate pairs. The rpd (reproducibility of duplicates) values are calculated as the difference between the values of the two duplicates, divided by the average of the duplicates and multiplied by 100%. Methods for TSS and VSS also came from "Standard Methods", 19th Edition.

The "Simulation of Single Sludge Processes" (SSSP) software was used to analyze plant operation. This software, developed at Clemson University (Bidstrup and Grady 1988) is based on the IWA Task Group Model ASM1 and includes processes for heterotrophic growth, nitrification, denitrification, decay, and hydrolysis. ASM1 is the simplest mathematical model developed by the IWA Task Group on Mathematical Modelling for Design and Operation of Biological Wastewater Treatment having the capability of realistically predicting the performance of single-sludge systems carrying out carbon oxidation, nitrification and denitrification (IWA 2000). Analyses of the mixed waste stream influent to the activated sludge basins along with actual plant and operations data were input to the SSSP software to calibrate the model based on actual plant performance, and to develop plant specific system and kinetic parameters for carbon and nitrogen consumption. Soluble carbon and nitrogen were assumed to be readily degradable, while particulate carbon and nitrogen were assumed to be slowly degradable. Data sets from five operating days were used to determine whether the parameters tended to be reasonably consistent over time. It is important to note that the goal of the model calibration herein was not to develop a complete model calibration with a single unique set of parameters describing system behavior. The goal was to develop a working model that could be used to assess the effects of nitrogen sources and operational strategies. The calibration strategy was to minimize adjustment of default parameters.

Once the model was calibrated, the SSSP software was used to test the effects of varying process conditions on nitrogen uptake to determine which strategies offered the most convenient and economical control, using equipment and basins currently available at the plant. These strategies included varying the ammonia supplement feed rate, the number of trains online, mean cell residence time (MCRT), and step feeding. The software was also applied to various individual process waste flow streams to determine the effect of a large loading from a particular process on ammonia supplement needs and effluent quality.

RESULTS AND DISCUSSION

Brewery Waste Streams Analyses

Table 2 is an overview of carbon and nitrogen constituents in waste streams from six specific brewery processes. These data were obtained over a period of only six days, and therefore do not represent the overall variability in the wastes. Variability of the data sets for each waste stream is represented by rpd, calculated as described above, using the highest and lowest values for each parameter. Over the 6-day period, the flow, DOC, SKN and NH_3-N were the most variable parameters, while TOC and TKN were less so. The conditioning waste stream varied the most, while the fermenting and yeast drying streams varied the least.

Brewery waste is by far the most concentrated waste stream in terms of TOC, followed by fermenting and conditioning. The streams from malting, yeast drying and packaging are lower in TOC, but all these streams are significantly more concentrated than typical municipal waste streams, which range from 150 to 400 milligrams per liter (mg/L) (CSU 2003a). Dissolved organic carbon (DOC) ranges from 42 – 92% of TOC. Malting and yeast drying are in the low range because much of the organic carbon is in the form of cell bodies and grain particles. Fermenting and conditioning have the highest DOC to TOC ratio, indicating that most of the organic carbon is in soluble form.

TKN values vary widely among waste streams, with yeast drying containing the most, followed by brewing, then fermenting. Malting, conditioning, and packaging have lower TKN values. With malting and packaging, the values are lower because the streams are simply more dilute in organic matter. In the case of conditioning, although high in TOC, its relatively low TKN may be because most of the stream is finished beer with relatively more sugar and ethanol, which do not contain nitrogen.

SKN concentrations range from 32 – 75% of TKN. The difference between TKN and SKN represents nitrogen in particulate form, such as grains, cellular mass, and coagulated protein forms such as trub (Hardwick 1995). These particulate forms are metabolized more slowly than the soluble forms, although some of this material is removed from the waste stream during primary treatment. SKN represents the soluble nitrogen, including organically bound nitrogen and NH_3-N. Some or all of this nitrogen is metabolized by the biomass during secondary treatment. The difference between SKN and NH_3-N is organically bound, soluble nitrogen. During metabolism, organically bound nitrogen is converted to NH_3-N, which is then utilized by the biomass. For all waste streams, the organically bound, soluble nitrogen makes up a larger portion of the SKN than the NH_3-N. In the brewing, fermenting, conditioning, and packaging streams, NH_3-N is negligible, and virtually all SKN is as soluble organic nitrogen.

Table 3 shows ratios of carbon (TOC, DOC) to nitrogen for the brewery waste streams. For healthy biomass metabolism, the ratio of carbon to nitrogen in the food supply should be approximately 10:1. To avoid excess extracellular polysaccharides (Linton et al. 1986 and Congregado et al. 1985) and resultant sludge settling problems (based on past operational experience), it

TABLE 2 Brewery Process Waste Stream Characteristics [A8]

Brewery Process (% of Total Flow)*		TOC mg/L	DOC mg/L	TKN mg/L	SKN mg/L	NH_3-N mg/L
Malting (30%)	Avg.	369	202	36.2	15.4	3.7
	rpd %	8	29	1	40	42
Brewing (10%)	Avg.	2694	2183	109	35	0.3
	rpd %	12	13	9	19	25
Fermenting (2%)	Avg.	1178	1018	63	45	0.1
	rpd %	11	2	6	8	26
Yeast Drying (3%)	Avg.	826	351	171	55	12
	rpd %	16	15	7	31	46
Conditioning (20%)	Avg.	1057	969	22	16	0.2
	rpd %	30	48	37	43	58
Packaging (18%)	Avg.	553	463	14.2	10.6	0.1
	rpd %	17	19	0.1	10.8	83

*Percentages do not add to 100%; the difference in streams not studied in this work.

TABLE 3 Brewery Process Waste Stream Carbon: Nitrogen Ratios in Various Forms

Brewery Process	TOC Ratios				DOC Ratios		
	TOC: TKN	TOC: SKN	TOC: SOrg N	TOC: NH_3-N	DOC: SKN	DOC: SOrg N	DOC: NH_3-N
Malting	10	25	35	107	13	18	55
Brewing	25	77	77	10,000	62	62	7,000
Fermenting	19	27	27	10,000	23	23	10,000
Yeast Drying	5	16	20	76	6.5	8	30
Conditioning	48	65	65	7,000	58	59	5,000
Packaging	39	52	53	5,000	44	45	5,000

is probably safer to have a ratio somewhat lower than 10:1 (more nitrogen relative to carbon) rather than be deficient in nitrogen. This philosophy may result in overfeeding where nitrogen is lacking and supplementation is used, as is the case with brewery waste. TOC:TKN ratios suggest that malting and yeast drying wastes provide sufficient nitrogen relative to carbon for healthy cell metabolism, with yeast drying providing an excess of nitrogen. This is somewhat misleading in terms of biomass health because part of the TOC and part of the TKN are in particulate form, and may not be metabolized to a significant extent. TOC:SKN ratios are significantly higher than 10:1 for all the waste streams, so by this measure none of the streams contain sufficient nitrogen. The TOC:SKN ratios suggest a significant need for nitrogen supplementation; however, the use of TOC is again misleading.

A more representative ratio in terms of biomass health is the DOC:SKN ratio, with both carbon and nitrogen in soluble forms that can be metabolized. These ratios indicate that only the yeast drying stream contains enough soluble nitrogen for healthy metabolism. This stream actually contains an excess of nitrogen that could be taken up by blending with a nitrogen-deficient stream, which is what happens in reality. The malting stream is slightly deficient in nitrogen, and the brewing and conditioning streams are the most deficient in terms of soluble carbon and nitrogen. In all cases, ratios of carbon to NH_3-N are extremely high and indicate severely nitrogen deficient streams, illustrating the importance of considering all sources of soluble nitrogen when determining feed supplement needs. The variety of DOC:SKN ratios among the waste streams suggests a wide variety of possible nutrient conditions in the mixed waste stream that reaches the secondary treatment process, from slightly to highly nitrogen deficient conditions, which will in turn determine the level of nitrogen feed supplement.

Mixed Brewery Waste Streams – Influent to Aeration Basins

Detailed data for waste streams entering the aeration trains on five separate days are shown in Table 4. These data were used to calibrate the model. These specific days were chosen because full data sets, including TKN, SKN and VSS, were available. The influent stream represents mixed brewery waste streams, downstream of the primary clarifiers and upstream of the aeration basins. At this point in the plant, significant solids have been removed, affecting particulate organic nitrogen and particulate organics. More importantly, supplemental ammonia feed is added upstream of the point where these samples were taken. The only ammonia source not included in the primary effluent at this point is the RAS, which contributes significant ammonia.

TABLE 4 Waste Treatment Plant Influent to Secondary Treatment Process [A10]

Date	4/24/04	7/3/04	7/10/04	9/26/04	10/17/04
Influent Stream – Primary Clarifier Effluent (PCE)					
Inert Particulates, mg COD/L	158	226	45	135	164
Particulate Organics, mg COD/L	310	570	254	446	716
Soluble Organics, mg COD/L	505	584	588	430	551
Soluble NH_3-N, mg/L	12.0	20.3	11.0	32.5	7.8
Influent Stream - RAS					
RAS Soluble NH_3-N, mg/L	25.3	57	30	20.6	15
RAS VSS, mg/L	10,240	9,280	11,120	9,220	9,640
Influent Stream – Combined Primary Clarifier Effluent and RAS					
Total Soluble NH_3-N, mg/L	15.5	29.9	16.0	29.3	9.8
Soluble C:NH_3-N Ratio	19.9	11.9	18.4	10.5	42.8
Soluble Organic N, mg N/L	14.9	12.1	12.4	22.8	20.1
Total Soluble N, mg/L	30.4	42.0	28.4	52.1	29.9
Soluble C:Total Soluble N Ratio	8.1	6.8	8.3	3.7	11.2
Biodegradable Particulate Org N, mg/L	24.6	36.9	11.9	30.3	21.2
Effluent Stream – Mixed Liquor					
Mixed Liquor VSS, mg COD/L	4,244	4,019	4,794	4,117	4,004
Mixed Liquor NH_3-N, mg/L	9.5	19.0	7.2	10.0	4.5

The soluble organic nitrogen is fairly representative of a mixed brewery waste stream and appears to carry through the primary treatment process intact. Some of the particulate nitrogen drops out with solids in the primary clarifier. The NH_3-N is significantly higher than expected from a blended brewery waste stream in all cases because ammonia supplement feed has been added. If only the NH_3-N is analyzed, which is commonly the case, the C:N ratios are generally greater than the optimum 10:1 needed for healthy biomass, suggesting nitrogen deficiency; however, when soluble organic nitrogen is also considered, the combined NH_3-N and soluble organic nitrogen is generally sufficient for healthy biomass. In general, the data suggests a tendency to overfeed nitrogen supplement. Operating based solely on ammonia can be confusing with a brewery waste stream that contains significant soluble organic nitrogen. For example, on July 3, 2004, the C:N ratio based only on NH_3-N is reasonable at 11.9:1, suggesting an adequate supplement feed rate; however, the effluent NH_3-N was 19 mg/L, suggesting overfeed. When the soluble organic nitrogen is also considered, the C:N ratio that day was 6.8:1, again suggesting overfeed.

Model Calibration

The SSSP software allows up to nine completely mixed bioreactor units with a variety of operating parameters including feed rates, step feed, recirculation, recycle, and dissolved oxygen concentration. The SSSP software does not model clarification, and it does not account for potential effects of nutrient imbalances or deficiencies on final clarification. Inputs are fairly simple and straightforward, allowing a fairly quick analysis of secondary treatment processes and, in particular, operational changes. The first step to using the software is to run it with actual plant operating data to verify kinetic and stoichiometric parameters, which govern nutrient uptake rates and may be different for different bacterial cultures. Once these parameters are set, the model can be used to investigate effects of operational changes, such as decreasing ammonia supplement, step feeding, decreasing sludge age, or adding an aeration basin.

Figure 1 shows the activated sludge treatment train schematic of the Coors PWTP. Three aeration trains available, each with a volume of about 1 million gallons (3,785 m^3). Each train is divided into three sections in series, with the first section making up 50% of the train and the last two sections making up 25% each. The trains are configured to step feed some portion of the influent to the second or third sections. The plant runs on pure oxygen and processes an average of 5 million gallons per day (MGD) of brewery waste, with COD concentrations ranging between 300 to 800 mg/L, with an average of about 500 mg/L. The trains are run in parallel and placed on line or taken off line as needed. RAS is added directly to section 1 of each parallel train.

Because the trains are operated in parallel, the SSSP configuration was simplified to one large train with three sections, Figure 2. The RAS input is included in the influent stream using the combined PCE and RAS data presented in Table 4. This configuration properly models performance and greatly simplifies data entry. Effects of one, two or three trains in parallel are modeled by adjusting the aeration basin volumes.

Selected plant operating parameters for days that were modeled are shown in Table 5. This is a fairly high rate plant with hydraulic retention time in the trains normally around 12 – 18 hours. It normally takes about 24 – 30 hours for the waste stream to move through the entire plant, from the bar screen to the final effluent flume. The data in Table 5 combined with that in Table 4 illustrate the wide variety of flow and COD loading conditions that can change rapidly from day to day.

Initial modeling of plant data was run with the default kinetic and stoichiometric parameters shown in Table 6. Parameters were then selectively changed as needed to improve the model matching with actual plant performance. After the oxygen saturation was increased to reflect pure oxygen aeration, the first priority was to model the mixed liquor concentration by altering the cell yield coefficient. The model then tended to produce effluent NH_3-N that was in reasonable agreement, with the NH_3-N analyses of the mixed liquor. The model tended to nitrify fairly readily with the plant parameters, and in practice nitrification is fairly rare in this plant. This was corrected by increasing autotrophic Ks values for NH_3-N and oxygen uptake. The rest of the default parameters gave reasonable results, suggesting the biomass in the plant behaves like typical biomass in terms of nutrient uptake.

A comparison of model results and actual plant performance with respect to mixed liquor volatile suspended solids (MLVSS) and NH_3-N are shown in Table 7. In all cases, effluent streams did not contain significant soluble organic nitrogen, and effluent COD was low. MLVSS concentrations shown in the table are fairly close to actual values because the cell yield coefficient was adjusted to force this to match. NH_3-N values, while not exact, are a reasonable match between the actual plant data and the model. Several attempts were made at adjusting kinetic and stoichiometric parameters to improve the match and in most cases another parameter would be adversely affected. For instance, adjusting the N in the biomass or particulates was expected to tie up nitrogen and therefore decrease the NH_3-N in the effluent, causing it to better match the actual plant performance. However, these materials also decay and hydrolyze in the trains, and this results in larger NH_3-N spikes in the last sections of the trains, resulting in an NH_3-N concentration that was similar to or higher than the original concentration. In reality, there are many operating and stream characterization variables and there is error associated with each, making a perfect match unlikely. The results were encouraging enough to warrant further use of the software to explore options for varying plant operations to improve performance and decrease ammonia.

FIGURE 1 Actual Plant Aeration Train Configuration

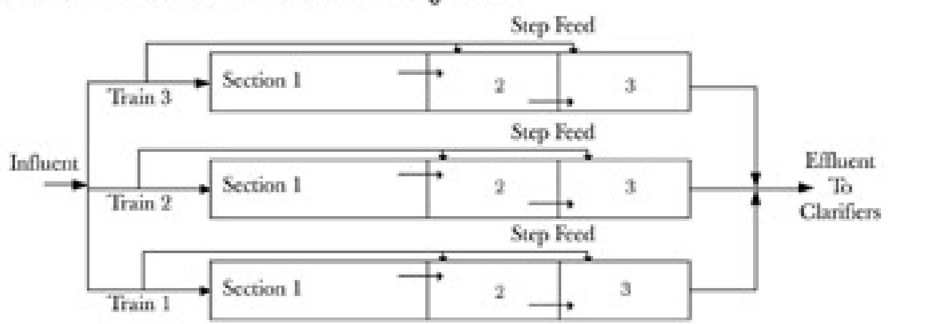


FIGURE 2 SSSP Model Configuration

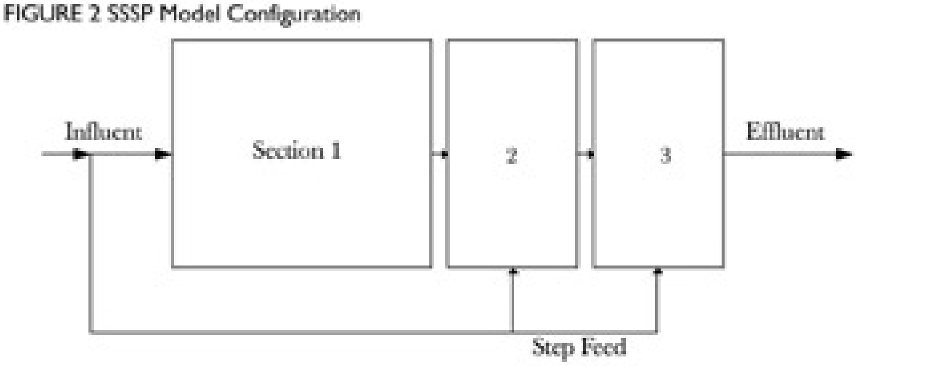


TABLE 5 Plant Operating Parameters

Date	4/24/04	7/3/04	7/10/04	9/26/04	10/17/04
Flow, MGD	4.75	5.12	6.47	4.33	4.75
RAS, %	36	36	36	36.5	38
MCRT, days	3.10	3.49	4.14	4.34	3.01
Trains on Line	2	3	3	3	3

Modeling of Process Control Strategies

The simplest and least expensive method of minimizing ammonia in the effluent is to limit or minimize the feed. In this case,

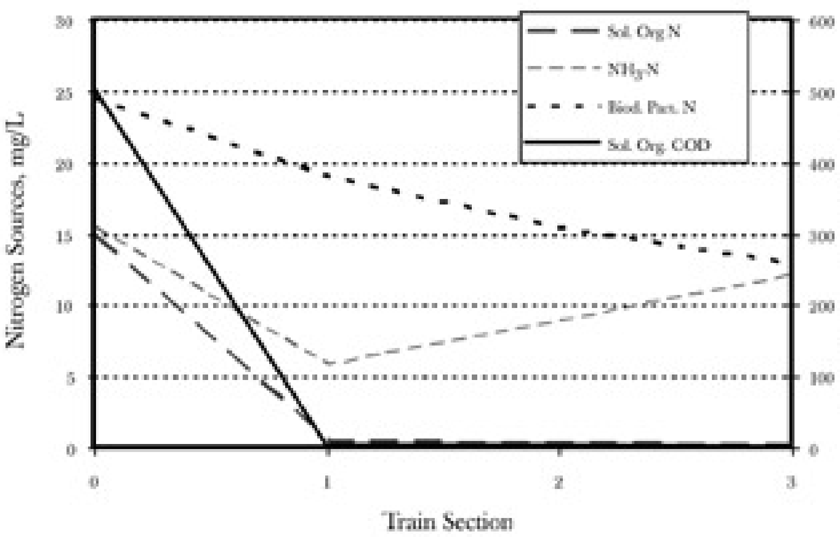
TABLE 6 Kinetic and Stoichiometric Parameters Used to Model Plant Data [A16]

Parameter	Heterotrophic Organisms		Autotrophic Organisms	
	Default	Altered	Default	Altered
µmax, d^{-1}	4.00		0.65	
Ks COD, mg COD/L	10.00			
Ks NH_4-N, mg N/L			1.00	5.00
Ks O_2, mg O_2/L	0.10		1.00	5.00
Yield, g/g	0.65	0.70 (4/24) 0.65 (7/3) 0.78 (7/10) 0.78 (9/26) 0.70 (10/17)	0.24	
b decay, d^{-1}	0.46		0.12	
Anoxic Growth Factor	0.80			
Ks NO_3, mg N/L	0.20			
Hydrolysis Rate, d^{-1}	2.20			
Hydrolysis Sat. Ratio, g COD/g COD	0.15			
Anoxic Hydrolysis Factor	0.4			
Ammonification, m^3/g COD^{-1}	0.16			
Frac. Part. Prod, g COD/g COD	0.08			
N in Biomass, g N/g COD	0.10			
N in Part. Prod., g N/g COD	0.10			
Oxygen (O_2) Sat. Conc., mg O_2/L	9.00	33.0		

TABLE 7 Comparison of Modeled Effluent and Actual Plant Effluent

	MLVSS, mg COD/L		NH_3-N, mg/L	
Date	Model	Actual	Model	Actual
4/24/04	4258	4244	12.1	9.45
7/3/04	4411	4019	20.4	19
7/10/04	4774	4794	3.9	7.24
9/26/04	4015	4117	15.1	10
10/17/04	3924	4004	2.5	4.49

FIGURE 3 Simulated Nutrient Profile Across Train for Modeled 4/24/04 Data MCRT=3.1 Days



the only available nitrogen would then be from soluble organic nitrogen in the influent and NH_3-N in the RAS. When ammonia feed was eliminated from the influent using the 7/3/04 data, the effluent NH_3-N dropped from 20.4 to 11.9 mg/L. When the 9/26/04 data was used the effluent ammonia decreased from 12.1 to 7.3 mg/L. There are many days when the plant appears to have sufficient nitrogen from organic nitrogen and ammonia nitrogen; however, there are also days when these two sources are not sufficient and eliminating ammonia supplement on these days could lead to unhealthy biomass and settling problems. The operator would need to know the soluble carbon to nitrogen ratio in order to make a decision. This would involve measurements of both soluble organic carbon and soluble organic nitrogen at least 2 or 3 times per day. This in turn involves use of in-line measuring devices or laboratory tests of grab samples. In-line devices, while available for soluble organic carbon, are not currently available for soluble organic nitrogen.

Figure 3 shows chemical concentration changes across each section of the modeled train for the 4/24/04 data. The model only generates influent and effluent points from each section and the straight line between these points is included to illustrate the trend. This presentation method is also used in Figures 6 and 7. This data represents the base case and does not include step feed. These changes clearly show that:

1. The soluble organic COD is consumed in the first section of the train.
2. The soluble organic nitrogen is consumed in the first section of the train.
3. Two thirds of the NH_3-N is consumed in the first section of the train.
4. NH_3-N increases in the last two sections of the train as a result of biomass decay, shown as a decrease in biodegradable particulate nitrogen.

This same type of profile was noted for the other runs. In all cases, nutrients in the feed are consumed in the first half of the train, and then NH_3-N increases throughout the rest of the train as biomass decays. These observations suggest that influent and effluent NH_3-N may not be sufficient to fully define nutrient conditions in the trains, because there is the possibility that NH_3-N may be fully consumed in the first section of the train, leaving nutrient conditions that are deficient in NH_3-N, at least temporarily, in the second section, until more nitrogen is released from decaying biomass. Another implication is that even if a strategy were developed to control nitrogen supplementation, a strategy to minimize nitrogen increases in the aeration trains would be useful as well. Further, if COD is fully consumed in the first half of the train, it might benefit the biomass and lead to more even nutrient utilization to try and operate such that COD is still being consumed in at least the second section of the train, with the third section available as a buffer zone to ensure full treatment prior to release to the environment. Some methods of accomplishing this were tested using the model with the 4/24/04 plant data, including step feeding, adjusting the sludge age, adjusting the recycle rate, and using a lower aeration system volume.

The effect of step feeding, illustrated for the 4/24/04 data in Figure 4, is to decrease NH_3-N in the effluent; however, the effect is probably not significant enough to use this as a tool specifically for this purpose. It is necessary to step feed most of the influent to the second section to achieve a measurable NH_3-N reduction, and at the same time the COD in the effluent increases. Step feeding does reduce the MLVSS concentration at the same return rate and concentration, which would reduce loading on the clarifiers. This is consistent with other work (Buhr 1984).

Adjusting the recycle rate of the RAS over a fairly wide range had no appreciable effect on the NH_3-N concentration in the effluent for the 4/24/04 data; however, different MCRTs did have a significant impact as shown in Figure 5. Decreasing the MCRT from the base case of 3.1 days, which resulted in an NH_3-N concentration of 12.1 mg/L, to an MCRT of 2 days, resulted in a decrease of 3.9 mg/L, or 32%, to 8.2 mg/L NH_3-N. Conversely, increasing the MCRT to 5 days increased the NH_3-N concentration in the effluent to 16.8 mg/L. The effect appears to be related to lower particulate organic nitrogen from the lower MLVSS concentrations. A potential disadvantage of lower sludge age is less resistance to spikes of organic COD loading to the plant and probably poor settling, which is not reflected here; however, the results do suggest that if the sludge is kept on the young side of the optimum window for a given plant, there is likely to be less NH_3-N in the effluent.

On 4/24/04, the plant operated with two trains on line. The fact that the treatment appeared to be essentially completed at the end of the first section, as shown in Figure 3, suggested that it might be possible to run the plant with one train under these operating conditions. This would minimize the biomass decay that was increasing the NH_3-N concentration in the effluent. Two additional cases were run, one with a single train on line and another case with three trains on line for comparison. It was necessary to adjust the MCRT to maintain the same mixed liquor concentration in the effluent; in reality this would be necessary to maintain the correct food to mass ratio and allow good settling in the clarifiers downstream. These results are shown in Figures 6 and 7 for one and two trains, respectively. Figure 6 shows the strategy appears to work well. The COD is consumed and NH_3-N in the effluent is reduced substantially from the base case,

FIGURE 4 The Effect of Step Feeding - 4/24/04 Data

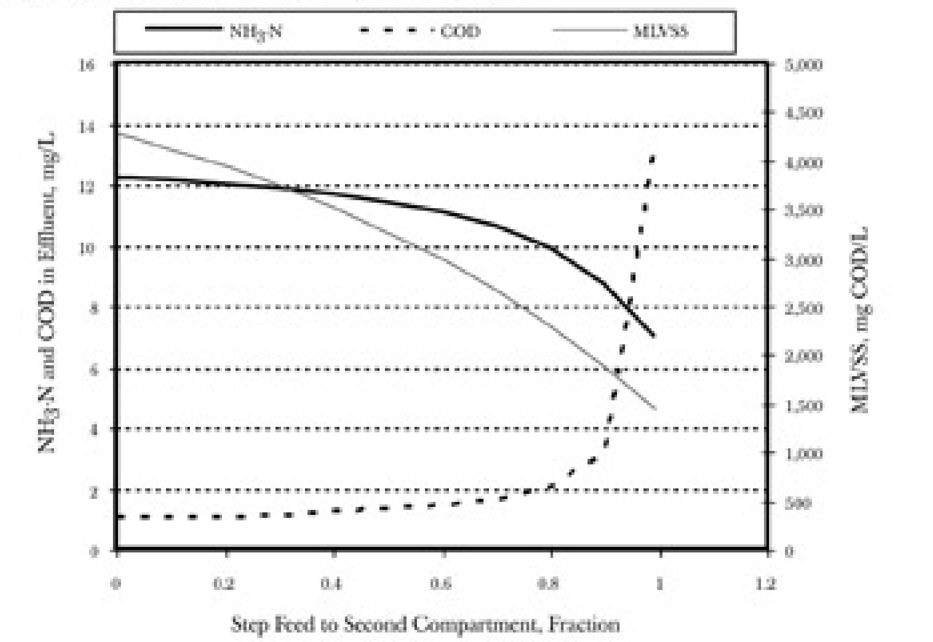
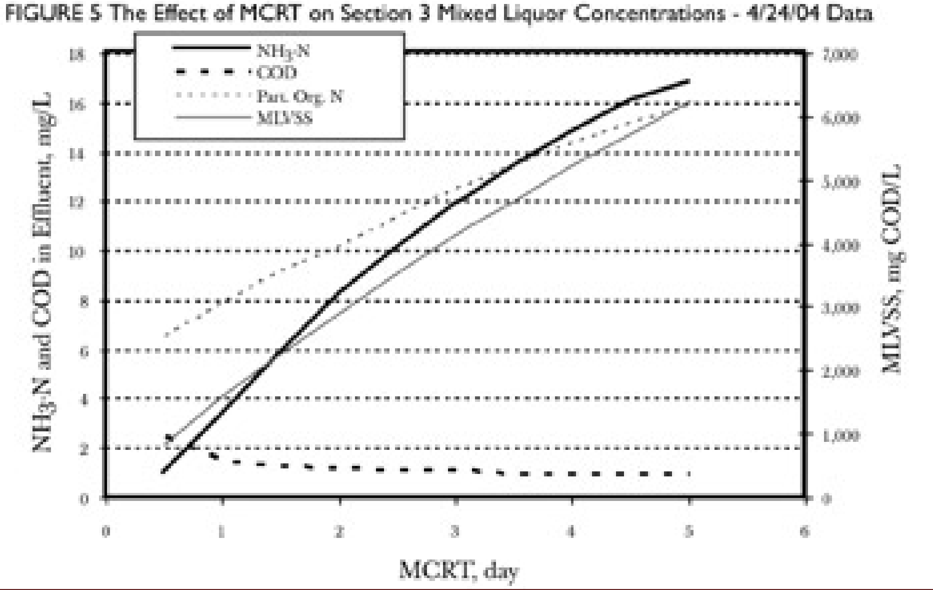


FIGURE 5 The Effect of MCRT on Section 3 Mixed Liquor Concentrations - 4/24/04 Data



from 12.9 down to 5.0 mg/L. Biodegradable particulate nitrogen does not decrease significantly and therefore does not release NH_3-N.

Figure 7, showing the results of three trains, is just as illustrative. In contrast to one train, with three trains, the effluent NH_3-N increases beyond the influent NH_3-N concentration and is higher than the base case, at 16.3 mg/L. Biodegradable particulate nitrogen continues to decrease through the trains.

CONCLUSIONS

1. Virtually all nitrogen that is naturally present in brewery waste is in a soluble or particulate organically-bound form, with very little ammonia.
2. The most representative ratio of carbon to nitrogen to indicate biomass nutrient conditions in a high-rate activated sludge treatment process for brewery waste is probably dissolved organic carbon to soluble Kjeldahl nitrogen (DOC:SKN) ratio.
3. Mixed brewery waste streams from several different processes may vary widely in soluble carbon:soluble available nitrogen ratios from day to day. Brewing and conditioning wastes have high DOC:SKN ratios of about 60:1 and need nitrogen supplementation, while wastes that are high in yeast, which may have very low ratios of 6:1, may require little or no supplementation. Waste streams that are high in waste from brewing, conditioning or packaging processes require significant nitrogen supplementation. Waste from the malting and fermentation processes require less nitrogen supplementation, and waste from processes high in yeast, such as yeast drying, require little or no nitrogen supplementation. A knowledge of influent process streams combined with in-line or routine analyses of influent for soluble organic carbon and organic nitrogen should be employed to make good nitrogen supplementation decisions. Train sections and train effluent streams should be monitored for NH_3-N to ensure sufficient nitrogen conditions throughout the trains. These data should be combined with influent stream data to further refine nitrogen supplement feed.
4. Influent and effluent soluble organic nitrogen concentrations may not provide sufficient information to fully define nutrient conditions throughout the aeration system. The effluent ammonia concentration may seem adequate when deficient conditions may actually exist in the middle sections of the aeration trains.
5. The SSSP software is a useful tool for exploring operational strategies for optimizing plant performance and controlling ammonia. Application of this software to simulate operation of the full-scale brewery wastewater treatment plant studied in this paper showed that:
   a. Step feeding has a minor effect on effluent ammonia concentrations unless a large portion of the influent is fed to the second sections of the trains.
   b. Decreasing MCRT, either by decreasing MLSS concentration or by decreasing the number of aeration trains on line, gave simulated decreases in effluent ammonia concentrations.
   c. Increasing or decreasing RAS recycle rate had no effect on simulated effluent ammonia concentrations.

FIGURE 6 Simulated Nutrient Profiles Modeled Across One Train for 4/24/04 Data
MCRT = 1.4 days

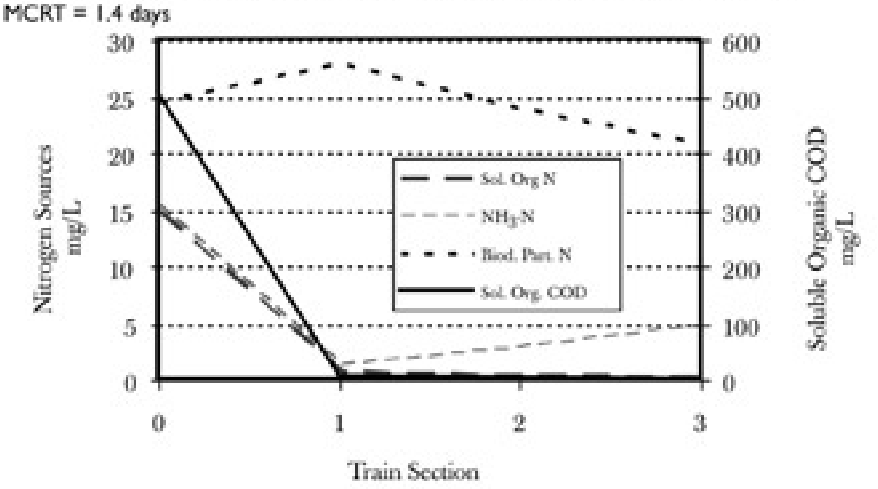
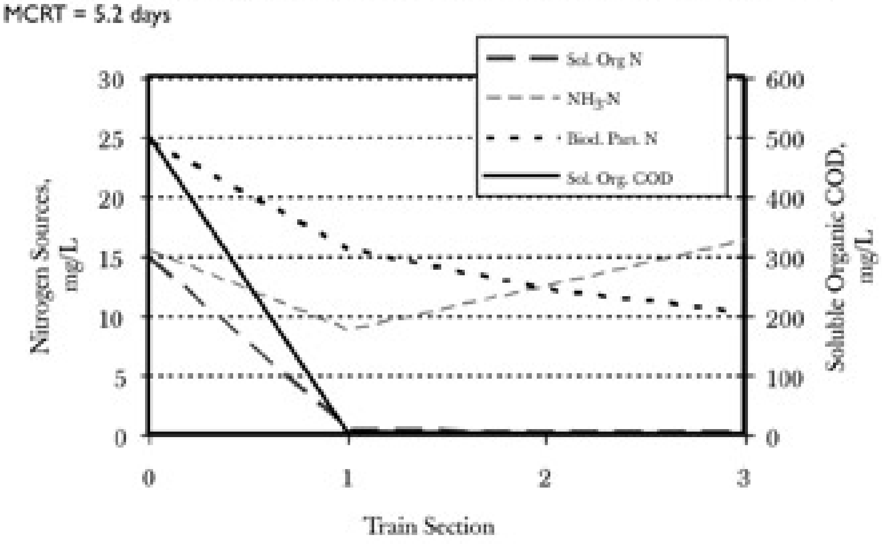


FIGURE 7 Simulated Nutrient Profiles Modeled Across Three Trains for 4/24/04 Data
MCRT = 5.2 days



ACKNOWLEDGEMENTS

We thank Coors Brewing Company for allowing us to present this work.

ABOUT THE AUTHORS

1 Plant Engineer, Coors Brewing Company, 17735 W. 32nd Avenue, VR 785, Golden, Colorado 80401

2 Associate Professor, Environmental Science and Engineering, Colorado School of Mines, Golden, Colorado 80401

REFERENCES

Ahn, Young-Ho, Min, Kyung-Sok, and Speece, Richard E. (2001) Pre-Acidification in Anaerobic Sludge Bed Process Treating Brewery Wastewater. *Elsevier Science*, Water Research Vol. 35, No. 18, pp. 4267-4276.

Bidstrup, Steven M. and Grady, C.P. Les. (1988) SSSP: Simulation of Single-Sludge Processes, Journal WPCF, Vol. 60, No. 3, pp 351-361.

Buhr, Heinrich O., Goddard, Madeline F., Wilson, Thomas E., Ambrose, Wallace A. (1984) Making Full Use of Step Feed Capacity. Journal WPCF, Vol. 56, No. 4, pp 325-330.

California State University, Sacramento (2003a) *Operation of Wastewater Treatment Plants, Volume II*, 6th ed.; Field Study Training Program, Sacramento, California.

California State University, Sacramento (2003b) *Industrial Waste Treatment, Volume II*, 2nd Edition, Field Study Training Program, Sacramento, California.

Congregado, F., Estañol, I., Espuny, M. J., Fusté, M. C., Manresa, M. A., Marqués, A. M., Guinea, J. and Simon-Pujol, M. D. (1985) Preliminary studies on the production and composition of the extracellular polysaccharide synthesized byPseudomonas sp. EPS-5028, Biotechnology Letters, Volume 7, Number 12, pp. 883-888.

Eaton, Andrew D., Clesceri, Lenore S., and Greenberg, Arnold E., *Standard Methods for the Examination of Water and Wastewater*, 19th Edition, American Public Health Association, 1995.

Hardwick, William A. (1995) *Handbook of Brewing*, Marcel Dekker, Inc.

Hough, J.S., Briggs, D.E., Stevens, R., and Young, T.W. (1994) *Malting and Brewing Science*, Vol. 2, Chapman & Hall.

IWA Task Group on Mathematical Modelling for Design and Operation of Biological Wastewater Treatment (2000) Activated Sludge Models: ASM1, ASM2, ASM2d and ASM3, IWA Scientific & Technical Report series.

Jenkins, David, Richard, Michael G., and Daigger, Glen T. (2004) *Manual on the Causes and Control of Activated Sludge Bulking, Foaming, and Other Solids Separation Problems, 3rd Edition*, CRC Press.

Linton, J.D.; Watts, P.D.; Austin, R.M., Haugh, D.E. and Niekus, H.G.D. (1986) The energetics and kinetics of extracellular polysaccharide production from methanol by micro-organisms possessing different pathways of C sub(1) assimilation. J. GEN. MICROBIOL. Vol. 132, no. 3, pp. 779-788.

Rittmann, Bruce E., and McCarty, Perry L. (2001) *Environmental Biotechnology: Principles and Applications*, McGraw-Hill.

Rodrigues, Ana C., Brito, Antonio G., and Melo, Luis F. (2001) Posttreatment of a Brewery Wastewater Using a Sequencing Batch Reactor, *Water Environment Research*, Volume 73, Number 1.

CHEMICAL ENGINEERING

BUILD YOUR ENGINEERING LIBRARY BOOK SERIES

Edited by Suzanne Shelley and the Editors of
Chemical Engineering

Written by engineers for engineers, each book contains practical, authoritative engineering articles from the pages of ***Chemical Engineering***

BOOK TITLES:

Liquid-Liquid and Gas-Liquid Separation (250 pages)
Includes articles on distillation, adsorption, absorption, stripping, liquid-liquid extraction, membrane separation, ion exchange, crystallization, evaporation, and more.

Environmental Management: Air-Pollution Control (300 pages)
Includes articles on technologies for managing gaseous emissions, NOx, SOx, particulate matter, and other airborne industrial pollutants, design tips for thermal and catalytic oxidation systems, emissions monitoring, relevant data and calculation methods, and more

Environmental Management: Wastewater and Groundwater Treatment (360 pages)
Includes articles on chemical, biological and physical treatment systems, and emissions-monitoring techniques, for industrial wastewater and groundwater; technologies include membrane systems, reverse osmosis, filtration, carbon-based adsorption, evaporation, aerobic and anaerobic digestion, and more

Plant Operation and Maintenance — Part 1: Chemical Process Equipment (380 pages)
Includes articles on operating and maintaining high-temperature equipment (boilers, heaters, heat exchangers, incinerators, heaters and more), rotating equipment (compressors, turbines and motors), pumps and valves, baghouses and electrostatic precipitators; coping with pressure buildup; avoiding leakage (gaskets, couplings and leak detection) and more

Plant Operation and Maintenance — Part 2: Procedures and Best Practices (390 pages)
Includes articles that share engineering and managerial recommendations for operating and maintaining plantwide systems and plant utilities (steam electricity, cooling towers), coping with corrosion and fouling, maximizing fire safety, protecting workers, managing tanks and monitoring levels, managing pipeline issues, and more

Fluid Handling (350 pages)
Includes articles on specifying, operating and maintaining pumps, valves, and flowmeters, coping with troublesome fluids and flow problems, pipeline issues, modeling, and more

Plant and Personnel Safety (385 pages)
Includes articles on safe handling and storage of hazardous substances, avoiding dust explosions, spill response, managing overpressure and thermal runaways, fire protection, process safety management, safety instrumentation, worker training, and more

Managing Bulk Solids (215 pages)
Includes articles on storage, weighing and feeding of bulk solids, particle characterization, separation and classification, pneumatic conveying, drying, managing dust emissions and electrostatic hazards, and more

Mixers and Mixing (220 pages)
Includes articles on specifying impeller, rotor-stator and static mixers, troubleshooting mixer systems, coping with problem fluids, modeling using computational fluid dynamics and simulation, blending solids, and more

Gas-Solid and Liquid-Solid Separation (160 pages)
Includes articles on particle separation using filters, cyclones, hydrocyclones, centrifuges, baghouses and electrostatic precipitators, drying systems and more

Thermal Management (250 pages)
Includes articles on heat exchangers and heat-transfer fluids, heaters and desuperheaters, drying, condensation, chilling, evaporation, quenching, temperature measurement, avoiding runaway reactions, and more

Pristine Processing (150 pages)
Includes articles on selecting and operating high-purity equipment, managing high-purity gases and chemicals, designing and operating cleanrooms, maintaining clean-in-place and steam-in-place systems, and more

Available in **3 different formats** to suit your needs:

1  Perfect-bound soft cover book

2  Spiral-bound soft cover book

3  CD-ROM

Go online to www.che.com to preview the Table of Contents of each book, and to place your order.

American Academy of Environmental Engineers (AAEE) members: Please use promotional code AAEE6735 when using the online order form.

Sponsorships Available!

To learn how your company can SPONSOR one or more of these books, please contact Helene Hicks, at phone: 212-621-4958 or hhicks@chemweek.com. The cost is $2,750 to sponsor a single title; $2,500 each when you sponsor more than one title. **Ask about our Group Sales & Bulk Volume Discounts!**

Put Your Academy Pride on Display

THE SHIRT

NOW AVAILABLE!
White, 100% cotton with the Academy logo prominently displayed in navy blue. Slightly dropped sleeves, deep armholes, extra give across the shoulders, and a straight bottom hem gives this comfortable shirt its classic golf style.

Machine washable. Available in Small, Medium, Large, X-Large, and XX-Large.

$25.00

THE PIN

$25.00

In Gold Plate.
A textured background dramatizes the lustrous polish of the letters and banding. Jewelry quality.

$10.00

In Cloisonné.
Gold-colored metal letters and banding surround a field of dark blue, fired enamel.

THE CERTIFICATE

Laminated Shown, $65.00
(Also available unmounted, $40.00)

Lost or misplaced your certificate? Want to have one on display at both your home and office? Your certificate displays your name, area of specialty certification, and date of certification. Certificates can be laminated on a solid wood base with a burl wood tone finish.

Call Academy Headquarters to order your Pride Package