The Periodical of the American Academy of Environmental Engineers®

Winter 2011 | Volume 47, Number 1

ENVIRONMENTAL *Engineer*

"Time to move the rubber tree plant"

– AAEE Executive Director Joseph S. Cavarretta

PLUS:

- Class of 2010
- 2011 Kappe Lecturer

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ENVIRONMENTAL Engineer

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FEATURES

DEPARTMENTS

by Brian P. Flynn, P.E., BCEE, *BFlynn4290@aol.com*

One in a Hundred Thousand

Q: ***What is the brief history of the Academy's Sponsoring Organizations?***

A: AAEE was born in 1955 with the critical support of five Sponsoring Organizations (SOs): APHA, ASEE, AWWA, WPCF (now WEF), and ASCE. Since then, the Academy has added other like-minded SOs, namely AWMA, AICHE, APWA, ASME, AEESP, NSPE, and SWANA for a total of 12. Each SO has a voting representative to AAEE's Board of Trustees (BOT), which meets twice per year.

Q: ***How important are SOs to the Academy?***

A: That's an interesting question. They are as important as they want to be. Certainly, not as important as they were when the Academy was in its infancy. Some of them provide some very nice supplemental support to us, such as participation in their national conferences and seminars, as well as other joint activities. SOs provide an 'outside' perspective to our BOT as we formulate policy for the Academy. They have played a positive role is helping us to become well known and strongly organized.

Q: ***Do SOs contribute money to the Academy?***

A: No. There are in-kind services that flow back and forth between the Academy and SOs, but no money changes hands. The Academy has stable finances. Unlike many professional organizations, we have had no drop off in revenues during the Great Recession. However, many organizations charge sponsors an annual fee – I would actually like to know what our members think of that. Should we do it? Email me!

Q: ***What do we do with our SOs?***

A: A really interesting question! A few do nothing more than fund the travel expenses and send a representative to our Board meetings. Others are heavily involved with us in joint seminars, conferences, etc. Other activities include mutual website links, efforts to promote certification, education, and articles in each other's magazines. We are beginning to devote some thought to strengthening and restructuring some of our relationships. I plan on personally doing a 'tour' of SOs to talk to them about more joint activities. We very much want to hold ourselves and our individual SOs jointly responsible for working effectively together. Sometimes this is harder to do in voluntary organizations, but we are confident that we'll make significant progress.

Q: ***You didn't mention ABET and CESB earlier. Aren't they SOs?***

A: No. We have four representatives *to* various commissions within The Accreditation Board for Engineering and Technology (ABET). We belong to this organization to help maintain and improve the quality of college level environmental engineering education. It actually costs us north of $30,000 per year to participate – an example of your dues at work!

The Council of Engineering and Scientific Specialty Boards (CESB) is the organization that monitors and governs our Board certification program. We have a representative to them, and pay a $5,000 fee annually to defray their costs of administering our certification. By the way, we also provide representatives to the Institute of Professional Environmental Practice (IPEP) and to a Liaison Council of the National Council of Examiners for Engineering and Surveying (NCEES).

Q: ***So, can you summarize where we are with our SOs?***

A: We value their contributions. We want, and will, develop more joint activities to our mutual benefit. I welcome member input on what we should do together with our SOs. I'm easy to reach. My email is at the top of the page.

Q: ***I know this isn't on topic, but what does the "One in a Hundred Thousand" at the top of the page refer to?***

A: Certainly not me! Actually it represents the rough ratio of certified Academy members to the total population of the US and points out the rarity of the skills that our members possess. EE

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The 2011 Officers and Trustees

Congratulations to the new Officers and Trustees for 2011 who took office on January 1. They are:

Brian P. Flynn	President
Michael W. Selna	President-Elect
Pasquale S. Canzano	Vice President
Howard B. LaFever	Treasurer
Cecil Lue-Hing	Past President
Gary S. Gasperino	A&WMA Trustee
Tapas K. Das	AIChE Trustee
Edward Butts	APHA Trustee
Lamont W. Curtis	APWA Trustee
Paul A. Bizier	ASCE Trustee
Jason C. Lynch	ASEE Trustee
Richard S. Magee	ASME Trustee
Steven J. Quail	AWWA Trustee
James R. Mihelcic	AEESP Trustee
Dan Wittliff	NSPE Trustee
Stephen G. Lippy	SWANA Trustee
Richard D. Kuchenrither	WEF Trustee
Otis J. Sproul	Trustee-at-Large
Sandra L. Tripp	Trustee-at-Large
R. Tim Haug	Trustee-at-Large
James F. Stahl	Trustee-at-Large
Joseph F. Malina, Jr.	Trustee-at-Large
Richard J. Pope	Trustee-at-Large

Committee Appointments

President-Elect Brian Flynn has finalized committee appointments for the Academy's 2011 program year.

Committee	**Chair**
Audit	Richard P. Watson
Awards	Cecil Lue-Hing
Honorary Member Selection Sub-Committee	Cecil Lue-Hing
Brewster Snow Student Selection	Cecil Lue-Hing
Bylaws, Policies & Procedures	Otis J. Sproul
Admissions	Sandra L. Tripp
Certification by Eminence	Cecil Lue-Hing
Membership, Development & Outreach	Michael W. Selna
Re-Certification	Lisa Woodward
Development & Upgrading of Examinations	Robert H. Gilbertsen
Air Pollution Control	Tapas K. Das
Environmental Sustainability	Brian P. Flynn
General Environmental Engineering	Clement B. Potelunas, Jr.
Hazardous Waste Management	James D. Fitzgerald
Industrial Hygiene	John M. Hochstrasser
Radiation Protection	Ronald L. Kathren
Solid Waste Management	Robert B. Gardner
Water Supply and Wastewater	Jeffrey H. Greenfield
Engineering Education	David A. Chin
Excellence in Environmental Engineering	Stephen R. Maguin
Finance	Howard B. LaFever
International Relations	Kumar Topudurti
K-12	Richard J. Pope
Nominating	Cecil Lue-Hing
Planning	Brian P. Flynn
Publications	C. Robert Baillod
Revenue Generation Work Group	Dan Wittliff
Seminars and Workshop	Sandra L. Tripp
Students and Young Professionals	Stephanie Boylard
Tau Chi Alpha	Robert Sharp, III
Website Work Group	Dan Wittliff

Specialty Certification Renewals

Have you renewed your specialty certification for 2011? If you haven't renewed by the time you receive this issue, then do so now! The deadline has already passed (December 31); however, you still have time before your certification lapses. You can renew right now by logging into the AAEE Center at *https://netforum.avectra.com/eWeb/StartPage.aspx?Site=AAEE* or visit AAEE.net and click on the red **Renew Online** button under membership. The AAEE Center is a secure web site.

Membership Growth and Application Deadline

AAEE granted 145 new certifications in 2010 – 114 are new Board Certified Environmental Engineers (BCEEs) and 19 are new Board Certified Environmental Engineering Members (BCEEMs). In addition to the 133 newly board certified profiled in this issue, 11 existing BCEEs were certified in a second specialty and one was certified in a third specialty. Included in this class are the first to be certified in AAEE's newest specialty, Environmental Sustainability (18).

Word of mouth and personal encouragement are the primary tools for recruiting new members. We wish to thank all of our members who take the time to recruit new applicants. If you have a colleague who is not yet Board Certified, encourage them to apply for Specialty Certification. The current AAEE application cycle ends on March 31, 2011. EE by Joseph S. Cavarretta, CAE

Time to Move the Rubber Tree Plant

Did you know that a standard marketing campaign to recruit new AAEE applicants requires at least seven 'touches' (e.g., customized postal mailings, emails, telephone calls)? AAEE's tight operating budget does not yet provide sufficient funds for such campaigns. Currently, most candidates apply after being encouraged repeatedly by a colleague or supervisor. For these reasons, the Academy primarily depends on you, the most highly respected within the environmental engineering profession, to identify and encourage applicants. Those who shoulder this critical responsibility know that it takes a few follow-up communications with each candidate to make sure he or she stays on track.

Attrition Rate vs. Application Rate

According to available data, AAEE's annual attrition ranges between 2% and 3% of members, a rate most associations only dream of attaining. Certainly members value their Academy certification. Nevertheless, economic conditions of 2009-2010 resulted in a high-range attrition rate of 3%. AAEE also experienced a 20% decline in applicants during 2010.[1] The resulting net growth of BCEEs and BCEEMs was 29 – just over 1%.

The Academy's Five-Year Strategic Plan[2] called for 100 net new certificants in 2010, and 150 net new in 2011. To reach the 2010 objective, AAEE needed to recruit 175 new BCEEs/Ms. To catch up to the 2010 objective and meet 2011 objectives, the Academy must rally to recruit 339 applicants by March 31 (76 to compensate for 2010 and 263 for 2011). Ladies and gentlemen of the Academy, this will be no small task. Your commitment is needed to move the rubber tree plant.

The Membership Committee volunteers and staff devote substantial time and effort to facilitate membership growth but cannot do it without Academy-wide assistance. Historically, less than two percent of members reach out to recruit and follow through with one new applicant (not including committed consulting firms that actively promote certification to staff). This is why the Membership Development & Outreach Committee encourages each member to recruit five new applicants (see Special Report on page 13) and to contact five existing BCEEs or BCEEMs and ask them to do the same.

One-to-One Recruiting

To reach the objective, it will take 12% of members volunteering to Share a Commitment by recruiting and following through with one applicant each. If you will Share the Commitment to help AAEE attain its March 31 objective, please email *jcava@aaee.net* and make your intentions known. Upon request, AAEE will assist your recruitment efforts by scheduling conference calls to answer your prospects' questions and supply you with materials. By achieving the Strategic Plan's goals for 2010-2011, the Academy can take long-needed concrete steps to invest in membership ROI such as raising awareness of, and demand for, BCEEs and BCEEMs among federal and state agencies and utilities; providing greater career-enhancing benefits and the recognition that BCEEs and BCEEMs deserve; adding new market-driven benefits for consulting firms; offering more educational initiatives (e.g., K-12 contests, workshops/seminars for public and industry); initiating webinars; implementing standard membership recruitment campaigns; and updating the Academy's office infrastructure. More important, a stronger Academy will add muscle to the mission, ultimately honoring those deceased diplomates who founded AAEE so many years ago and living up to their vision: "[Members ...] will be recognized for their expertise in environmental engineering specialties...as evidenced by their positions of leadership and service in public and private institutions" and the mission: "[AAEE] is dedicated to the practice of environmental engineering to ensure the public health, safety, and welfare to enable humankind to co-exist in harmony with nature."

Top-Down Recruiting

CEOs and senior officers of consulting firms and public agencies can do the work of many individuals to help the Academy move the rubber tree plant (by March 31). It only takes a few minutes each week to encourage your environmental engineers to reach out and achieve the personal satisfaction and recognition that comes with earning this exclusive certification. Your firm will also benefit. If you email prospective applicants' names, telephone numbers, and email addresses to *jcava@aaee.net,* the Academy will be pleased to follow up with candidates on your behalf. For groups of five or more, AAEE is willing to schedule a convenient conference call or arrange a personal visit to answer questions. Email *jcava@aaee.net.*

Applying is easy: Prospects only have to visit the AAEE.net Home Page and click on How to Apply, under Membership. The new electronic form can be filled out online, printed, and mailed. AAEE also offers a comprehensive brochure that summarizes certification, describes who can apply and how to apply, and relates the value of becoming certified. To request a packet of printed brochures, email Joyce Dowen at *Jdowen@aaee.net.*

Share my commitment, and that of the Membership Development & Outreach Committee volunteers in 2011 to help AAEE move the rubber tree plant. We have high hopes. EE

> "Your commitment is needed to move the rubber tree plant."

Footnotes

1 Admissions Committee 2010 Report to the Board of Trustees

2 Copies of the Strategic Plan are available: email *jcava@aaee.net.*

Awards & Honors

Dennis M. Kamber, P.E., BCEE has been inducted into the Virginia Tech's College of Engineering's Academy of Engineering Excellence. The Academy of Engineering Excellence was established in 1999 to honor the career achievements of Virginia Tech's alumni. Mr. Kamber, Senior Vice President of Arcadis, has been board certified in Water Supply and Wastewater Engineering since 1983.

Specialty Certification

Michael Cline, P.E., BCEE was recently board certified in a second specialty. Mr. Cline, Vice President, Hannum Wagle & Cline Engineering (Indianapolis, IN), has been board certified in Water Supply and Wastewater Engineering since 2003. His second specialty is Environmental Sustainability Engineering.

Mario Cora-Hernandez, Ph.D., P.E., BCEE was recently board certified in a second specialty. Dr. Cora-Hernandez, Public Health Engineer III, ARMA, MDE (Baltimore, MD), has been board certified in Air Pollution Control Engineering since 2007. His second specialty is Environmental Sustainability Engineering.

Stephen Couture, P.E., DEE/BCEE was recently board certified in a second specialty. Mr. Couture, Senior Associate/ Environmental Engineer, The Cadmus Group, Inc. (Watertown, MA), has been board certified in Water Supply and Wastewater Engineering since 1988. His second specialty is Environmental Sustainability Engineering.

Edward Patrick Hagarty, D.Sc., P.E., BCEE was recently board certified in a second specialty. Dr. Hagarty, Department Head, URS (Gaithersburg, MD), has been board certified in Hazardous Waste Management Engineering since 1993. His second specialty is Environmental Sustainability Engineering.

Travis Hylton, P.E., BCEE was recently board certified in a second specialty. Mr. Hylton, Environmental Engineer, NAVFAC Pacific (Pearl Harbor, HI), has been board certified in Water Supply and Wastewater Engineering since 2003. His second specialty is Environmental Sustainability Engineering.

Michael Kavanaugh, Ph.D., P.E., BCEE was recently board certified in a second specialty. Dr. Kavanaugh, Principal, Geosyntec Consultants (Oakland, CA), has been board certified in Water Supply and Wastewater Engineering since 1983. His second specialty is Environmental Sustainability Engineering.

Howard LaFever, P.E., BCEE was recently board certified in a second specialty. Mr. LaFever, Principal, GHD, Inc. (Cazenovia, NY), has been board certified in Water Supply and Wastewater Engineering since 1982. His second specialty is Environmental Sustainability Engineering.

Jose Marti, P.E., BCEE was recently board certified in a second specialty. Mr. Marti, Principal, Technical Consulting Group (San Juan, PR), has been board certified in Water Supply and Wastewater Engineering since 1998. His second specialty is Environmental Sustainability Engineering.

Wayne McFarland, P.E., BCEE was recently board certified in a second specialty. Mr. McFarland, Principal, GHD, Inc. (Cazenovia, NY), has been board certified in General Environmental Engineering since 1994. His second specialty is Environmental Sustainability Engineering.

William Moriarty, P.E., BCEE was recently board certified in a second specialty. Mr. Moriarty, Office Manager, King Engineering Associates, Inc. (Jacksonville, FL), has been board certified in Water Supply and Wastewater Engineering since 1996. His second specialty is Environmental Sustainability Engineering.

Douglas Owen, P.E., BCEE was recently board certified in a second specialty. Mr. Owen, Vice President, Malcolm Pirnie, Inc. (White Plains, NY), has been board certified in Water Supply and Wastewater Engineering since 1994. His second specialty is Environmental Sustainability Engineering.

James Sheetz, P.E., BCEE was recently board certified in a third specialty. Mr. Sheetz, Supervisory Environmental Engineer, Naval Facilities Engineering Command (San Diego, CA), has been board certified in Water Supply and Wastewater Engineering since 1972 and Hazardous Waste Management Engineering since 1987. His third specialty is Environmental Sustainability Engineering.

In Memoriam

Edward H. Bryan, Ph.D., P.E., BCEE, of Chevy Chase, Maryland, passed away December 13, 2009, at the age of 85. Dr. Bryan was a Life Member of AAEE and had been board certified in Water Supply and Wastewater Engineering since 1975.

Rafael Miranda-Franco, P.E., BCEE, of Guaynoba, Puerto Rico, passed away May 10, 2010, at the age of 91. Mr. Miranda-Franco was a Life Member of AAEE and had been board certified in Sanitary Engineering in 1956. He was among the very first class certified by AAEE and received special recognition at AAEE's 50th Anniversary Banquet as being among the Academy's longest-serving members.

Robert Frank Roskopf, Ph.D., P.E., BCEE, of Minnetonka, Minnesota, passed away on July 9, 2010, at the age of 71. Dr. Roskopf, an Emeritus Member of AAEE, was board certified in Water Supply & Wastewater Engineering in 1988.

Richard Vaughan, P.E., BCEE, of Ormond Beach, Florida, passed away on May 27, 2010. Mr. Vaughan was a Life Member of AAEE and had been board certified in General Environmental Engineering since 1974.

Letters to the Editor

I want to thank you and the contributing authors for the wonderful article about Bill Boyle's career and life. I was a student of Bill's in the late '70s/early '80s and he had a huge impact on my life and career, becoming a lifelong friend (as he has to many other of his former students and colleagues). I particularly enjoyed learning more about his early years, including the football injury that led him to the University of Cincinnati (and kept him geographically near Nancy).

One thing that was missed in the article is that Bill received an Honorary Membership Award from the Water Environment Federation in 2007. This is a very prestigious award given in recognition of a career of service to the water profession and to WEF and its member associations. My understanding is that this award is given out very judiciously, to less than 0.5% of WEF membership. Bill was well deserving of that recognition, as well as the many other awards he's received.

Thanks again for the great article.
Bill Marten, P.E., BCEE, Milwaukee, WI

This issue of *Environmental Engineer* is "over the top." Wow!

Years ago, it was my privilege to draft the material that became the article on Dwight Metzler. The use of 'testimonials' by former students and others in this issue's article on William Boyle added a lot. I wish I'd have thought of that!

Thank you, too, for discussing the new AAEE Center exhaustively. That'll doubtless aid its use.

Jon M. Rueck, P.E., BCEE
Silver Lake, KS EE

Special Report from AAEE's Membership, Development & Outreach Committee

by Michael W. Selna, P.E., BCEE, AAEE Vice President

A recent survey of our members verified what we have presumed for some time. The key reasons why engineers choose to become Board Certified are **professional accomplishment, esteem in the profession and peer recognition** – in three words, a ***Badge of Excellence***.

The Academy's Membership, Development & Outreach Committee has been studying results of past membership campaigns and found two factors that consistently stand out:

1. New members often apply because they are encouraged by existing members whom they look up to, and
2. Senior members of firms, agencies and academic institutions can have a large impact by distributing a memo or letter to staff urging them to join.

Membership is critical to the Academy in many ways. Because the Academy is largely a volunteer organization, our members play a huge role in the ongoing functioning of the Academy. They are involved in everything from creating and administering exams, reviewing items for publication, serving on committees, organizing seminars and workshops, judging award applications and engineering education accreditation. In addition to the outstanding volunteer support, our programs require funding, and annual recertification fees represent about 70% of the Academy's income.

Membership growth is so important to the survival of existing programs and development of new programs that the Academy's five year Strategic Plan contains numerical goals that are shown in Exhibit 1. The straight blue line is a future projection based on past growth levels. The red line represents the Strategic Plan goals that need to be achieved to allow an improving level of service to our members.

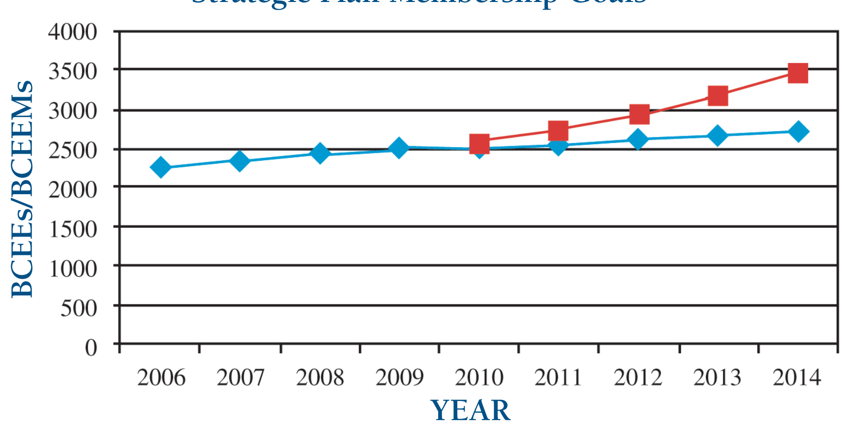
As we enter our next application cycle ending March 31, 2011, please take a few minutes to reflect on what AAEE has meant to your career and how you can pass that on to another deserving engineer. Please take the time to not only display your own *Badge of Excellence*, but to encourage several of your colleagues to join the Academy so that they may also experience the satisfaction of being part of an elite group of engineers. With less than 2,600 Board Certified Environmental Engineers in the world, you represent a very select group and deserve to be proud of your professional accomplishments. One thing is certain: those whom you encourage to join will be flattered that you think highly enough of them to recommend they join the Academy.

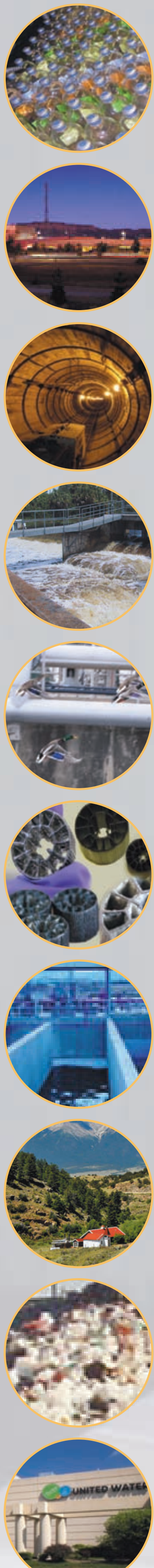
The *Badge of Excellence* membership campaign is underway and ends March 31, 2011. Here are some concrete things you can do to help the Academy:

1. Be the encourager for at least five colleagues whom you think would be interested in joining. For details and an application form, visit aaee.net, and look under **Membership**. Download an application form by clicking on the **How to Apply** link.
2. Contact at least one senior level person (perhaps in your own firm or agency) whom you think would be willing to send a memo or letter to staff encouraging them to join. AAEE will supply a mock up. Contact Joe Cavarretta at *JCava@aaee.net*.
3. Contact at least five of your "local" BCEEs/BCEEMs to encourage them to invite five colleagues to join.
4. Hand out AAEE information at a local meeting of one of the Academy's Sponsoring Organizations. Contact Sammi Olmo to obtain the materials: *jsolmo@aaee.net*.
5. Give a brief AAEE intro at a local professional meeting between now and March 2011 (AAEE will supply the Power Point).
6. Display the Badge of Excellence logo in your email signature. See *aaee.net* for instructions.

Environmental Engineering is very important to the global community and will become even more so in the future. Your achievement of Board Certified status is a model for those that will follow in the profession – but only if you make the effort to pass it on! EE

Exhibit 1
Strategic Plan Membership Goals





GET THE RECOGNITION YOU DESERVE

Enter the 22nd Annual

Excellence in Environmental Engineering®

Competition

AAEE's Excellence in Environmental Engineering Competition singles out those projects or programs which testify to the genius of mankind for recognition. Its criteria defines what it takes to be the best — a holistic environmental perspective; innovation; performance and customer satisfaction; and contribution to an improved quality of life and economic efficiency.

Entries are accepted in the following categories:

- Design
- Environmental Sustainability
- Operations/Management
- Planning
- Research
- Small Firms
- Small Projects
- University Research

Prize-winning entries are automatically eligible to enter the International Water Association's Project Innovation Awards global competition.

To obtain entry guidelines, submission instructions, and details, go to http://www.aaee.net and click on Excellence in Environmental Engineering.

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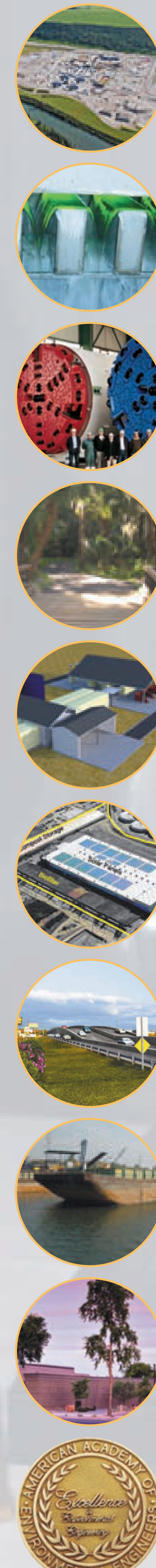

Entry deadline is February 1, 2011.

AEESP and AAEE:

Unifying Elements of Education and Practice

by Nancy G. Love, Ph.D., P.E. Professor and Chair, Department of Civil and Environmental Engineering, University of Michigan
President, Association of Environmental Engineering and Science Professors

Recently, the leadership of AAEE and the Association of Environmental Engineering and Science Professors (AEESP) reached an agreement to share space in each other's periodic publications, with a goal of enhancing communication between our respective communities. Indeed, strengthening and advancing cooperation between the academic environmental engineering and science community and others is included in AEESP's mission.

As one who has had a foot in practice as well as a foot in academia, I'm cognizant of the fact that while our two communities share several common goals and an overarching passion towards a clean and healthy environment, we also harbor some significant differences in our execution toward achieving those goals. Indeed, at times it seems we are at odds with each other's goals and needs when, in fact, I think it is more due to differences in our approach in trying to get to the same endpoint. For example, the AEESP Biannual Conference workshop entitled *Addressing the Shortage of Environmental Engineers in the Professional Pipeline* that was held during the 2007 AEESP biannual conference in Blacksburg, Virginia, highlighted that many of the academic institutions producing graduate students are being pushed to produce more Ph.D.s for reasons related to rankings and modern day university budget models, while practice needs more masters students, which universities are funding to a lesser degree than in the past. In another example, both organizations have great interest in the education of environmental engineers, with AEESP members teaching the next generation and AAEE members employing them. The accreditation question that fits in the middle of these respective activities sometimes causes consternation between our groups, as there are academic constraints and realities that many academics believe are not considered to a sufficient enough degree in new and proposed ABET criteria. Likewise, people in practice see training needs that academics are not meeting as we train the future environmental engineering workforce.

How do we bridge these interfaces? Education and practice hold equal importance in creating a healthy and sustainable environment in which we live. I do believe that there are opportunities to focus our collaborative energies at some of these points of intersection so that we can reduce the amount of energy we lose simply to friction.

In that vein, a planned workshop entitled *Needs & Frontiers of Education in Environmental Engineering* that is being driven by some AEESP and AAEE academic members is being planned for early April 2011 in Washington DC (advertisement coming out soon), with a goal of bringing together leading environmental engineering educators and researchers to define and advance major directions in the educational challenges for environmental engineering, and to develop a sustainable forum for sharing breakthroughs and needs in education methods at the frontiers of environmental engineering.

I propose a series of preparatory conversations by a subgroup of members from the workshop planning committee, myself, and non-academic AAEE members to frame a specific white paper to be part of this workshop that is focused on identifying mutually beneficial solutions to recruiting more masters students into environmental engineering who will go into practice. I also hope that our effort can be presented as part of the workshop dissemination that will occur at the AEESP Biannual Conference to be held July 10-12, 2011 in Tampa Florida (*http://aeesp2011.com/*). In this way, we can bridge our respective interests in developing the environmental engineering talent pool, and advance the environmental engineering profession. I welcome your thoughts (*nglove@umich.edu*). EE

THE

CLASS of 2010

These individuals were Board Certified in October 2010.

From the first applicants in 1956 to the 133 Board Certified Environmental Engineers and Board Certified Environmental Engineering Members listed on the following pages, the Academy has undergone growth and changes, but has never wavered from it's core objective to "identify and credential persons with special capabilities in environmental engineering."

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

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

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

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

Carl E. Adams,
Jr., Ph.D., P.E., BCEE
WW
Principal & Global Practice Area
Integrated Industrial Wastewater
Management
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Dr. Adams received his B.S. degree in Civil Engineering and M.S. degree in Sanitary & Water Resources Engineering from Vanderbilt University and PhD. in Environmental Health Engineering from the University of Texas, Austin. He is a licensed P.E. in Texas and Kentucky with more than 40 years experience.

Craig D. Adams,
Ph.D., P.E., BCEE
GE
J.L. Constant Distinguished
Professor & Chair
University of Kansas
Department of Civil, Environmental &
Architectural Engineering
Lawrence, KS 66045-7526

Dr. Adams received his B.S. degree in Chemical Engineering, and M.S. and Ph.D. degrees in Environmental Health Engineering from the University of Kansas. He is a licensed P.E. in Kansas with more than 26 years experience.

Peter Adriaens,
Ph.D., BCEEM
GE
University of Michigan
174 EWRE Building
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Ann Arbor, MI 48109-2125

Dr. Adriaens received his B.S. and M.S. degrees in Environmental Science and Engineering from State University of Gent Belgium and PhD. in Soil & Environmental Science from the University of California Riverside. He has more than 25 years experience.

Franklin Agardy,
Ph.D., BCEEM
GE
President
Forensic Management Associates
723 Chiltern Road
Hillsborough, CA 94010

Dr. Agardy received his BCE degree from New York City College and M.S. and Ph.D. degrees in Sanitary Engineering from the University of California, Berkeley. He has more than 55 years experience.

Jorge T. Aguinaldo,
BCEEM
WW
Vice President Business
Development
Doosan Hydro Technology
912 Chad Lane
Tampa, FL 33619

Mr. Aguinaldo received his B.S. degree in Chemical Engineering from Adamson University, Philippines and M.S. in Environmental Engineering from the University of South Florida. He has more than 36 years experience.

Donald M. Altier,
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Project Manager
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2010 AAEE **West Coast** Event a **Success**

by Wendy Wert, P.E., BCEE

On September 23, the American Academy of Environmental Engineers (AAEE) hosted its annual West Coast Event titled *Excellence in Environmental Engineering (E3)* at the Metropolitan Water District's (MWD) headquarters in Los Angeles. The 2010 AAEE West Coast Event began with alfresco networking in the patio area. Guests then proceeded to the MWD boardroom for the technical portion of the program.

AAEE Vice President Mike Selna welcomed attendees with a brief overview of the Academy. A primary objective of the Academy is to certify environmental engineers in their area of expertise, which include Air Pollution Control, General Environmental Engineering, Hazardous Waste Management, Industrial Hygiene, Radiation Protection, Solid Waste Management, Water Supply/Wastewater Engineering and, most recently, Environmental Sustainability. Board Certification is the next step beyond Professional Engineering licensure. Annually, the Academy administers the Excellence in Environmental Engineering® Competition to identify and reward achievement in the field of environmental engineering. This year's event showcased two Southern California international E3 award-winning projects.

Vice President Selna introduced the first Speaker, Chairman of the Board of Directors for the Metropolitan Water District, Tim Brick. Chairman Brick serves as a passionate water quality advocate through local, state, and federal associations. He is a Director for the national Alliance for Water Efficiency, an Advisor to the Water Resources Center at the University of California Berkeley, and a key developer of MWD's World Water Forum, which provides global water education grants to Southern California colleges. Chairman Brick's presentation shared key water-enhancing strategies from his substantial experience.

The featured project, MWD's Inland Feeder Program won the (E3) **Environmental Sustainability Honor Award**. The Inland Feeder is a 44-mile long, 12-foot diameter water conveyance system that was planned, designed, and constructed with environmental stewardship as one of its guiding principles. The $1.2 billion facility, completed in September 2009, ensures water supply reliability for nearly 19 million residents by mitigating the impact of ongoing climate change on the water supply and potential service interruptions caused by earthquakes on nearby faults. With the Inland Feeder

Attendees enjoy dinner

Featured Speaker, Dr. Kent Sorensen, Jr. of CDM

Attendees network in the patio area of MWD's Los Angeles headquarters

Featured Speaker, Chairman Tim Brick of MWD

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operation, Metropolitan can now fully utilize the largest water supply/conveyance system constructed in Southern California since the 1960s.

Chairman Brick broadened the discussion by challenging water quality professionals to consider our global water situation: 1.1 billion people do not have access to safe drinking water (one-sixth of the world's population), and 2.2 million people die every year from diseases associated with a lack of access to safe drinking water, inadequate sanitation, and poor hygiene. In North America, we are experiencing water supply and quality challenges. Three percent of all the energy used in California is consumed to move water to Southern California. In addition to energy efficiency concerns there are supply constraints. For example, pumping restrictions are in place in the bay-delta to protect the delta smelt, and we are experiencing a drought cycle in the Colorado River Basin. We need to identify new local water resources to address these concerns.

Chairman Brick suggested that local conservation efforts result in "new water." Irrigation is a substantial consumer in this arid region. Public education efforts that result in drought tolerant plant selections reduce the local irrigation demand. Another potential source of 'new water' could be local reclaimed resources. For example, MWD and its member agencies are partnering with Sanitation Districts to consider the use of highly treated (reverse osmosis) recycled product water as a viable local supply. Chairman Brick acknowledged that there are quality concerns, such as the potential for endocrine disrupting compounds associated with the full-scale development of this resource. Therefore, the first step is jointly funded research to assess the appropriate level of treatment and corresponding uses for local recycled water resources.

Vice President Selna then introduced the second Speaker, Dr. Kent Sorenson, Jr., Vice President and Assistant Chief Technical Officer at CDM. Dr. Sorenson is an environmental engineer experienced in groundwater characterization and remediation. His work focuses on in situ remediation of contaminants, including aspects of microbiology, hydrogeology and geochemistry. Dr. Sorenson described CDM's patented groundwater technology that is being applied to reduce the migration of contamination plumes and remediate sources, which describe another of Chairman Brick's potential 'new water' resources.

The featured project, CDM's Technology for InSitu Biodegradation of Perchlorate and Nitrate won the **Superior Achievement Award**. This program, located in Rancho Cordova, developed a patented process called Gaseous Electron Donor Injection Technology (GEDIT) that successfully remediates contaminates in deep soil. CDM collaborated with the US Department of Defense, and Aerojet-General Corporation to develop this technology.

Perchlorate is widely used as an oxidizer in rocket fuel, munitions, fireworks, and road flares. Due to past ground disposal during manufacturing and testing, perchlorate still leaches into groundwater from soil. As an endocrine-disrupting compound, perchlorate can interfere with thyroid function, leading to serious health issues. Until now, remediation technologies for perchlorate and nitrate have not effectively addressed source contamination in soil that leaches into groundwater. CDM collaborated with the US Department of Defense Environmental Security Technology Certification Program and Aerojet-General Corporation to research, develop, and prove an innovative in situ bioremediation process. In field tests, the patented technology successfully remediated perchlorate and nitrate in soil beyond the 90% reduction goal.

An essential component of Certification is the Academy's continuing education requirements. The 2010 West Coast Event provided the membership with an enlightened and inspired training opportunity. Through the practice of "Excellence in Environmental Engineering" the profession continues its journey toward making universal access to safe water a reality. EE

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The 2011 Kappe Lecturer

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Dr. Patterson is the author of two books on industrial wastewater treatment, the editor of a three-volume series on industrial pollution prevention, co-editor of a nine-volume series on water quality management, and has authored more than 100 other book chapters and technical papers. He was Chair of the WEF Journal *Water Environment Research* Board of Editors. He has served as an international consultant and advisor to numerous industries and government agencies, including the US Congressional Office of Technology Assessment, the US EPA, Department of Defense, and Department of Justice, the Illinois Pollution Control Board and Illinois EPA, the Kentucky Department of Natural Resources, the New York State Hazardous Waste Center, and the Ohio EPA.

During 1983-84, Dr. Patterson served as Executive Director of the State of Illinois Hazardous Wastes Task Force. He has served as Chair of the International Joint Commission Expert Committee on Engineering and Technological Aspects of Great Lakes Water Quality, and as Chair of the State of Illinois Effluent Standards Advisory Panel. Dr. Patterson was appointed a Charter Member of the US EPA National Advisory Council for Environmental Technology and Policy. In addition, he chaired the Fourth International Conference on Environmental Engineering Education, sponsored by AEESP and convened in Toronto, Canada. His Bibliographic Listings include:

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Abstracts of Lectures Offered

Remediation of Contaminated Sediments: Technical Options and Environmental Consequences

According to the US EPA, contaminated sediments continue to be a significant environmental problem that, due to release of contaminants from the sediments back into the ecosystem, impairs the beneficial uses of many waterbodies and is often a contributing factor to the thousands of fish consumption advisories that have been issued nationwide. Clean-up of contaminated sediment 'megasites' cost in excess of $50 million. There are often similarities among contaminated sediment sites. For example, at half of 60 Tier 1 sites tracked by the EPA, polychlorinated biphenyls (PCBs) were the primary contaminant of concern, while metals drove the risk at a third of the sites and PAHs at a fifth of the sites. There are a limited number of remedial approaches for such sites, including monitored natural recovery (MNR), sediment capping, fixation of pollutants within the sediments, or physical removal of the sediments by excavation or dredging. Each remedial approach has advantages and, often serious, disadvantages and environmental consequences.

This Seminar addresses the 'pros and cons' of alternative contaminated sediments remedial approaches, and considers the utility of multiple approaches within individual sites. The presentation focuses on the Lower Fox River, Wisconsin, which flows from Lake Winnebago northeast to Green Bay, and drains into Lake Michigan. The Lower Fox River (LFR) megasite includes approximately 39 miles of the LFR as well as the Bay of Green Bay, one of the major bays of Lake Michigan, and is one of the nations' largest sediment remediation sites.

River bottom sediments throughout the 39-mile length of the River and extending into Green Bay are contaminated by historical discharges of wastewaters containing PCBs from paper mills and Publicly Owned Treatment

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Works (POTWs) located along the River. The PCB wastewater discharges resulted from the manufacturing, de-inking, and recycling of carbonless copy paper. It has been estimated that 279,000 to 881,000 pounds of PCBs were released to the River, almost entirely prior to 1972. The PCB contamination persists today. The contamination has led to excessive body burdens of PCBs in fish, to the point that only a catch-and-release fishery is advised on the River.

The sediments of the LFR and to a lesser extent, the Bay, have been the focus of investigation and remediation efforts for decades. This presentation overviews the remedial options evaluated for the contaminated sediments of the River, and the consequent environmental advantages and risks associated with each remedial approach.

Control of Industrial Metals:

Conventional and Advanced Technologies

Many industrial and combined industrial-municipal wastewaters contain excessive concentrations of metals pollutants. Technically efficient and cost-effective control of such pollutants is dependent upon and accomplished within a complex matrix of wastewater and treatment technology variables. These variables include aspects such as:

- The target metal, or combination of metals, requiring control;
- The initial raw wastewater and required effluent concentrations of the target metal(s);
- The speciation (oxidation state, types and concentrations of complexing agents, organic vs. inorganic nature, etc.) of the target metal(s);
- Aspects of the wastewater matrix which might suppress, or enhance, the efficacy of a candidate treatment technology;
- The kinetics of a specific treatment technology, for a specific wastewater matrix and treatment technology configuration;
- The reliability and stability of performance of alternative candidate treatment technologies; and
- The cost-effectiveness (for the treatment of the liquid phase, and for the management of the treatment residuals [e.g., sludge, regenerant brine, filter backwash, etc.]) of the candidate treatment technologies.

Simplistic equilibrium modeling is rarely adequate for reliable technical prediction of complex industrial wastewater behavior. As a consequence, bench-scale and/or pilot-scale treatability studies are typically necessary in order to evaluate alternative treatment options, and their associated advantages and disadvantages. However, an understanding of wastewater treatment chemistry is essential in designing such treatability studies including in specifying their associated experimental variables, in properly interpreting the results of those studies and, most importantly, in translating those results to full-scale application. This Seminar presents an introduction to technical options, and some permutations of approaches in application of such technologies, to effective control of industrial metals pollutants. EE

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Environmental Engineer: Applied Research and Practice

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Sustainability and the Phosphorus Cycle: Inputs, Outputs, Material Flow, and Engineering

David A. Vaccari, Ph.D., P.E., BCEE, Stevens Institute of Technology

ABSTRACT

Phosphorus is well known to environmental engineers as an environmental issue because of its role in eutrophication of surface water. Environmental engineers tend to be concerned with how society interacts with its environment through its outputs (wastes). Sustainability is concerned with broader issues of our interaction with the environment, including both outputs and inputs (resources). (Environmental engineers have traditionally been involved with some inputs, notably water resources.) In the popular mind, sustainability is mostly about energy resources and global climate change. Environmental engineers are likely to add water resources to the list of concerns. But it is important to think more broadly in terms of material flow and life cycles to quantify inputs and outputs and to assess our ability to satisfy these needs indefinitely. This review examines phosphorus resources as an example of this broader view, and discusses ways in which environmental engineers may be well poised to make contributions in dealing with the resulting challenges.

INTRODUCTION

Sustainability is obviously not just about energy and water – it also encompasses material resources, as well as other resources such as land, labor, financial resources and technological innovation. For example, according to Gordon, et al (2006): "Providing today's developed-country level of services for copper worldwide (as well as for zinc and, perhaps, platinum) would appear to require conversion of essentially all of the ore in the lithosphere to stock-in-use plus near-complete recycling of the metals from that point forward." Phosphorus is one of the resources that may become critical within a few decades. This has been recognized by many who have looked at this issue (including some in the phosphate industry). The World Phosphate Institute (IMPHOS) is an organization of phosphate producing companies from North Africa and other producing nations. A past president of IMPHOS has stated: "With the anticipated requirements for phosphate for agricultural and industrial uses, the world is likely to run out in the near future of low-cost recoverable phosphate rock."

Environmental engineers have long recognized the resource value of our wastes. This is why solid waste incinerators are called "resource recovery plants," and why the material formerly known as sewage sludge is now "biosolids." Accordingly, biosolids are being exploited as a source of energy, nutrients, and organic matter for soil amendment. We have sought beneficial use of our waste byproducts, but mostly as a more economical way to dispose of them. BNR stands for "biological nutrient removal," not "biological nutrient recovery." However, there has been considerable activity recently to develop technology for recovery of nutrients from wastewater for reuse (Ashley et al, 2009).

Obviously, reduction, reuse and recycling can never be 100% efficient. Losses occur at numerous steps along the way from the mine to the plate, and some of these will always be unavoidable. Accordingly, virgin inputs will still be required. Where do we obtain our phosphorus? When I put this question to a farmer once, his answer was "Agway." It turns out that the phosphorus in fertilizer comes from mined deposits formed in coastal zones tens or hundreds of millions of years ago, as well as igneous formations. Unfortunately, according to USGS data, these deposits seem to be more spatially limited even than oil. 84% of the world's economic reserves are controlled by just five countries (Jasinski, 2010). The U.S. has been the source of about one-third of the world's production in the last century, and 80% of that has come from a single geographic area: a region of central Florida east of Tampa known as Bone Valley. Furthermore, the U.S. economic reserves are sufficient at current rates of exploitation for only about 40 years and production rates have been declining since 1981. Increasingly, the U.S. will have to rely on imported phosphate rock (PR). Most of that will probably be supplied by the custodian of the world's largest reserves – Morocco – which controls an estimated 36% of world economically exploitable reserves (and some 45% of the larger category of "base reserves"). Furthermore, if all known economic reserves are exploited at current rates, they would be exhausted in about a century.

Eighty percent of phosphorus production is used in agriculture. The mined phosphate rock is separated from impurities such as sand and clay in a process known as beneficiation. The product is reacted with sulfuric acid to produce the waste product gypsum ($CaSO_4$) and phosphoric acid. The phosphoric acid may then be reacted with ammonium hydroxide to produce a variety of products such as monoammonium phosphate. Raw PR may contain significant amounts of toxic impurities such as cadmium and uranium, much of which winds up in the gypsum byproduct. Due to the slight radioactivity of this material, it is stockpiled at fertilizer manufacturing plants in huge 'gypstacks.' The uranium may be an economic byproduct in some cases.

World population is expected to increase 38% by 2050 (U.S. Census, 2009).

This will drive demand for phosphorus fertilizer. Demand for phosphate is expected to grow at a rate of 2% per year in the near term (FAO, 2008). From 1993 to 2008 the global production of phosphate rock increased at an average rate of 2.3% per year, while world population over the same period increased at a rate of 1.3% per year (Vaccari, 2010). Thus, it seems that phosphorus production is driven by more than population increases. The conventional wisdom is that the additional increase is due to improved living standards leading to improved food quality, such as the proportion of meat in the diet. It may also be due to an increased nonfood use of agricultural products, such as production of biofuel from corn and sugar cane. Furthermore, increases in both food and non-food uses of agricultural production may force increased use of less productive arable land, which may require higher rates of irrigation and fertilizer usage. Thus one may anticipate a collision between supply and demand, producing shortages and/or high cost for food. Already in 2008, high prices for food caused by peaks in the cost of fertilizer and energy and increasing scarcity of water for irrigation resulted in "rice riots" in some parts of the world (Cordell and White, 2008).

Only about 17% of the phosphorus in fertilizer makes it into the human diet (Cordell and White, 2008). Major losses along the way include agricultural erosion and improper land application of animal wastes. Improved conservation may forestall the possibility of shortages and high prices, and produce improvements on the environmental issues as well. This suggests that there may be many opportunities for conservation to extend the life of our resources.

However, there is some question as to whether the needed increase in phosphorus production can be achieved, let alone sustained. Unlike energy, there is no alternative for phosphorus in food production (Jasinski, 2010). Also unlike energy, though, phosphorus can be recycled. What phosphorus and energy have in common is that both can be conserved. Phosphorus recovery, reuse and conservation present opportunities for environmental engineers to be involved.

Currently, economic incentives alone may not be sufficient to encourage the development of phosphorus recovery technology, although the technology is starting to be implemented in the United States, largely to improve phosphorus removal from wastewater. Several countries that are entirely dependent on phosphorus imports have adopted forward-looking policies. Sweden has been particularly pioneering in this respect. Their Environmental Protection Agency has proposed "an intermediate target for P-recycling that by 2015, at least 60% of the phosphorus in wastewater shall be restored to productive soil, of which half should be returned to arable land." (Stark, 2004) Germany has also announced goals for recycling phosphorus from sewage. Both countries have a considerable amount of academic and commercial activity related to the phosphorus cycle.

THE RESOURCE AND PRODUCTION PICTURE

Phosphorus is mined in mostly marine deposits containing phosphate rock (PR), which consists largely of various forms of hydroxyapatite and fluorapatite. The typical mining grade has about 13% phosphorus by weight. The resources that are exploitable under current economic conditions are termed "reserves." Resources that may be exploitable under improved economic conditions (higher prices, improved technology) are termed the "reserve base." Other phosphate resources may not be included in these categories due to heavy metal contamination or location. For example, there are huge deposits under the continental shelf off North Carolina that are not included in the USGS reserves or reserve base. In another example, much of the Florida deposits have and continue to become unavailable due to residential and commercial development of the overlying land (FIPR, 2010).

Figure 1 shows the cumulative discovery of phosphate rock resources in the 20th century up to 1982. Over the past century, 78% of the increase in estimates of global reserves came from only four individual discoveries. And these four were located in only two general locations: North Carolina, USA, and Morocco/Western Sahara. The final cumulative value from this figure is 105.6 Gigatons (Gt) PR. This can be compared to USGS estimates of available reserves, and

Figure 1
Cumulative Discovery of Global Phosphate Rock Resources (based on Sheldon, 1987)

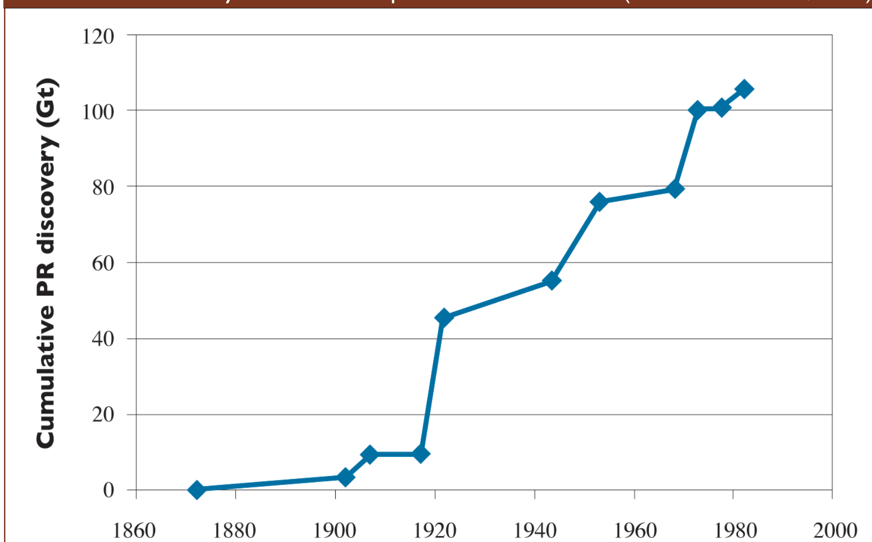


Table 1
Phosphate Rock Production and Resources Data for 2008 (data from Jasinski, 2010)

	Mine Production (Mt/yr)	Reserves (Mt)	Reserve Life (Years)	Reserve Base (Mt)	Base Life (Years)
Morocco and Western Sahara	28.0	5,700	204	21,000	750
China	50.0	4,100	82	10,000	200
South Africa	2.4	1,500	625	2,500	1,042
United States	30.9	1,200	39	3,400	110
Jordan	5.5	900	164	1,700	309
All other countries	49.9	2,000	40	8,150	163
World Total	**166.7**	**15,400**	**92**	**46,750**	**280**

cumulative PR production to date, which add to 22.5 Gt PR. The difference may be attributed to factors where availability of known resources may be limited by problems with composition or location.

Table 1 shows five countries that have the largest amounts of reserves, expressed as megatons (Mt) along with their rates of phosphate rock production in 2008 (based on Jasinski, 2010). Together these five countries control 89% of the world's reserves and are responsible for 70% of its annual production.

Several of these countries deserve special attention. Although China has the second largest reserves and the largest rate of production, it has restricted its exports by a 130% tariff. Countries such as Japan and Korea have depended on China for phosphorus, and this has alarmed them. It may be argued that China is doing the prudent thing and preserving an essential mineral to satisfy its future needs. This behavior is consistent with other moves by China to secure its future resources such as in food supply, iron, copper, and rare earth metals (of which China produces 95% of the world's supply). It has been said that, "China has a shopping list; it's called the periodic table" (Verosub, 2010).

Morocco is described as the "Saudi Arabia of phosphorus." It holds the largest deposits of phosphate rock in the world, and is currently ramping up its production capability. A large fraction of its production comes from the country to the south, Western Sahara, which is militarily controlled by Morocco. The world's longest conveyor belt (100 km) connects Western Saharan phosphorus mines to the coastal processing and shipping facilities. In the 1980's, an insurgency would periodically cut the belt, cutting off a large fraction of the world's phosphorus supply. Since then, however, Morocco has consolidated its control over the region, giving the monarchy effective ownership of a huge fraction of the world's potential for food production.

As mentioned above, the U.S. has produced one-third of the world's production since 1900. 17% of that was exported as PR; much of the rest was converted to fertilizer before export. Since 2004, the U.S. no longer exports PR. However, imports have grown to 9% of domestic production. The estimates of remaining reserves are about 54% of the amount that has been mined to date.

The estimates of reserves, such as those listed in Table 1, do not include possible new reserves such as undiscovered deposits or resources that may be converted to reserves by improved economic or technological conditions. Some say that mining companies limit their exploration to several decades of supply. In the case of phosphorus, there are reasons to rely on the current numbers. First is the spotty history of discovery that was mentioned above. Secondly, prudence would suggest that we shouldn't rely on such a contingent approach for a mineral such as phosphorus upon which life is so dependent. Finally, there has been a comprehensive country-by-country inventory of global PR deposits, known as Project 156 (Cook and Shergold, 1986).

How long will global resources last? One of the most common indices of adequacy of resource supply is the lifetime computed by dividing the reserve by the production rate, as shown in Table 1. In any case, the reserve life index indicates that the United States will approach depletion in less than 40 years. We will then depend on imported reserves, but these have an expected lifetime of less than a century. At that point, demand will result in an increase in prices for PR that will render the reserve base exploitable, and there seems to be several centuries available in this category.

However, there are some caveats to the possibility. First of all, an increase in real prices for fertilizer does not bode well for farmers in many countries. Even in Morocco, half of the farmers cannot afford fertilizer for their crops. In late 2008, PR prices spiked to seven times the historic price level, before settling back in 2009 to 54% above the average from 1993 to 2006. Keep in mind that energy is also a large component of agricultural costs, for irrigation, transportation, as well as manufacturing of nitrogen fertilizer, which is made from air and natural gas. Cost increases in all these combined to produce spikes in food costs in late 2008, in turn resulting in the civil disturbances mentioned above. This shows how food is linked to the interaction among a number of sustainability issues besides phosphorus including energy, water, soil conservation, and even climate change, which may produce dislocations in arable regions.

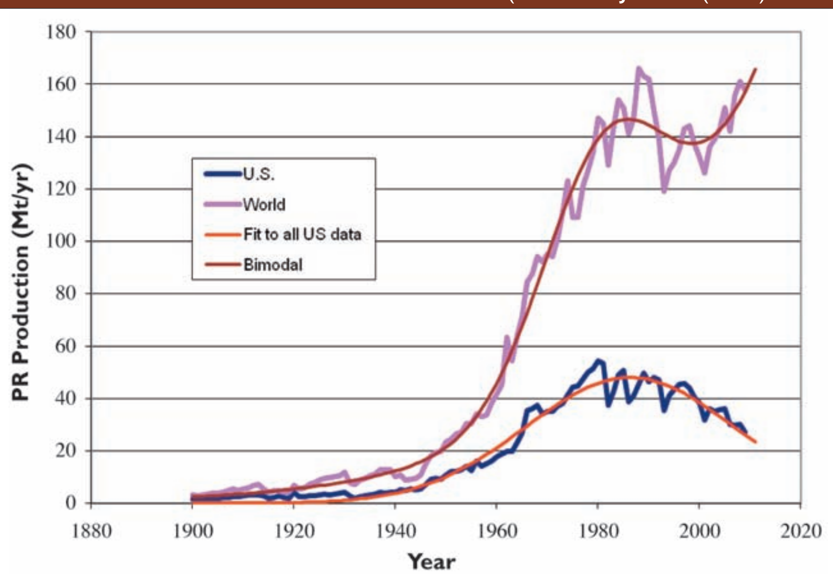
Furthermore, Van Kauwenbergh (2010) of the International Center for Soil Fertility and Agricultural Development (IFDC) recently produced an assessment that places reserves at 3.8 times the USGS figures, for a reserve lifetime of 380 years. If true, these data would affect the immediate urgency of the phosphorus situation, although not the long-term sustainability issue. The additional reserves identified by the IFDC are what are known as "inferred" reserves, and have not been verified by on-site prospecting with respect to grade or purity, nor have they yet been independently verified. In addition, some argue that resource scarcity begins to have an impact when half of the "ultimately recoverable resource" has been depleted, producing a peak in resource production. "Peak phosphorus" has been predicted to occur by around 2035, based on USGS data [Cordell and White, 2008]. If per capita PR consumption remains at recent levels, and if population increases are as predicted by the United Nations, then the point of half-depletion of reserves would be expected to occur based on the IFDC estimates by the year 2145 (Vaccari and Strigul, 2010).

The sources of error in the numerator of the resource lifetime index are the possible increases in reserves mentioned above. The denominator of this index may be biased by the likelihood of increases in production with time also mentioned above. Thus both are liable to increases, and it could be argued that using the existing values may cancel some of the error. However, there are several other indices to describe the resource picture besides the resource lifetime. These include prices (in constant dollars) and purity of the ore. Both of these also point to increasing scarcity. The price situation has already been described. Industry data suggests that "the phosphate content of pre-beneficiated ore is already decreasing by around 1% per decade" (Steen, 1998).

Examination of phosphate production trends shows that U.S. production clearly peaked around 1989 as shown in Figure 2. Global production exhibits a temporary peak at the same time, followed by a temporary decline. This is widely attributed to two factors. First, the fall of the Soviet Union, which was farming marginal lands that subsequently came out of production. The second reason was that farmers in developed countries realized that they were using more fertilizer than they required, and became more efficient (Smil, 2002). After a sharp correction, the growth in global phosphate production has now resumed its former rate of increase.

Additional resources may have issues with contamination, location, purity, and carbonate content. In the 1970s and '80s a large study of all known phosphate deposits in the world was conducted by the International Geological Correlation Programme, known as Project 156 (Cook and Shergold, 1986). This study estimated the total world resources at about 10 times the base reserves listed in Table 1, enough for a millennium at current production rates. However, "perhaps as much as two-thirds of the known resources are composed of carbonate-rich phosphate rock for which satisfactory beneficiation technology has yet to be developed on a commercial scale." This is because high carbonate levels greatly increase the demand for sulfuric acid in phosphoric acid production. And even sulfur may be a limiting resource in our economy. Phosphoric acid production from phosphate rock is the largest use of sulfuric acid.

Figure 2: Global and U.S. Phosphate Rock Production, with Gaussian Model fit to U.S. Data and Bimodal Gaussian Fit to Global Data (data from Jasinski (2010)



Location problems include depth below overburden, underwater location, or remoteness from transportation networks. The U.S. actually has large resources buried under the continental shelf off North Carolina and elsewhere along the eastern seaboard amounting to some 9000 Mt, enough to continue the current global production rate by another 50 or 60 years. However, the cost of recovering these resources would require that fertilizer prices, and therefore food prices, would have to be significantly higher than at present.

Many PR deposits contain significant amounts of heavy metal contaminants. Of particular concern are cadmium, uranium and other radionuclides. The Florida deposits contain 9 ppm Cd and 101 ppm U_3O_8. Moroccan deposits contain 15 and 185, respectively (EFMA, 2000). Finland and Sweden have restricted fertilizers containing more than 50 ppm Cd. Radiation protection measures may be required for those handling the fertilizer product (Ragheb, 2010).

Gypsum ($CaSO\text{-}_4$) is produced by the reaction of sulfuric acid with phosphate rock (itself composed of hydroxyapatite or fluorapatite). This byproduct is often stockpiled in huge mildly radioactive 'gypstacks' located at manufacturing facilities. This material may be classified as a low-level radioactive waste due to the residual uranium and decay daughters such as radon. The ultimate disposal of this material has been deferred pending development of acceptable beneficial use or treatment, but there is also a potential to recover uranium during the fertilizer production process.

THE PHOSPHORUS CYCLE AND MATERIAL FLOW ANALYSIS

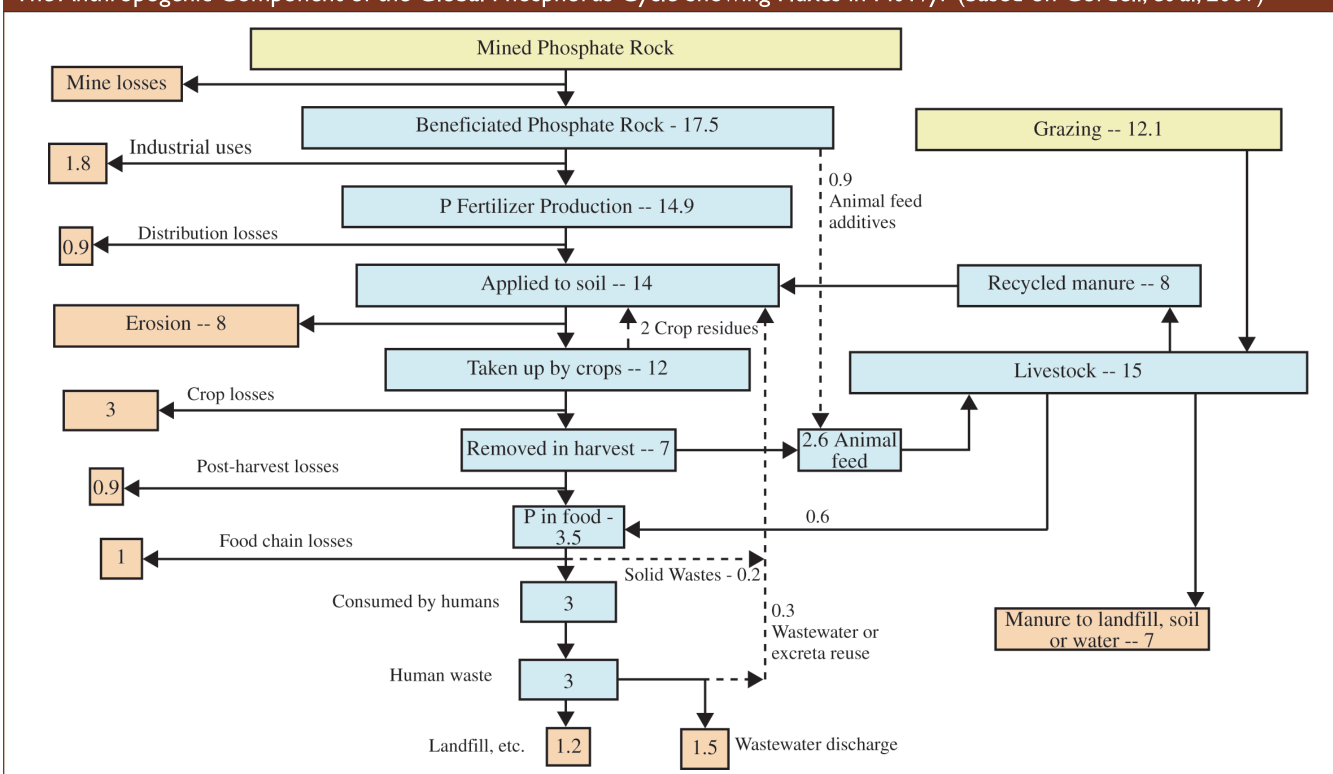
The roles of an element such as phosphorus in our economy and ecology may be examined using a material flow analysis (MFA). An MFA consists of reservoirs or stocks of the material represented by boxes, connected by arrows representing flows of material from one reservoir to another. Figure 3 shows a different graphical representation of material flow of the anthropogenic component of the global phosphorus cycle using data from 2002 (Cordell, et al, 2009). In this version, the boxes themselves represent flows of phosphorus (except for minor flows shown as dotted lines). The length of each box is proportional to the flow it represents. This figure makes it easier to see where there are opportunities to conserve phosphorus by reduction, recycling or reuse. (Note that some of the fluxes do not balance exactly, either due to difficulties in measuring these quantities, or because there may be accumulations in some of the stocks in the system.) Not shown is that over geologic time (tens to hundreds of millions of years) phosphorus that finds its way to the ocean may return to the land as part of the lithospheric cycle.

The largest loss to the environment that probably has the most technically and economically feasible potential for reuse is the loss of about half of the nutrient content of animal waste. Concentrated animal feeding operations produce large volumes of animal wastes. In the U.S., only about half of this material is properly returned to agricultural use. Much of it is either accumulated in waste piles or applied to lands in amounts beyond what can be assimilated by crops, therefore resulting in excessive runoff.

A similar amount of phosphorus is lost directly from cropland by soil erosion, but this will be more difficult to control. Phosphorus is strongly bound to soil particles. Past practices of overfertilization increased this loss. Agricultural practices known collectively as conservation agriculture (described below) can reduce this loss, but it is likely to remain significant even with intensive practices.

Of particular interest to environmental engineers is the 3 Mt/yr flow of phosphorus as human wastes. Only about ten percent is currently reused. About 40% winds up in landfills. The balance is discharged to surface waters, where it contributes to environmental problems. There has been a considerable amount of effort to remove phosphorus from this flow for environmental protection, as well as to recover it for recycling (Mavinic, 2009). Although this may be an important contribution to reducing the demand for phosphate rock, it has to be recognized that human usage is only about 17% of that demand.

Figure 3:
The Anthropogenic Component of the Global Phosphorus Cycle Showing Fluxes in Mt P/yr (based on Cordell, et al, 2009)



Smil (2002) estimated the anthropogenic flux at 21 Mt/yr (somewhat larger than the 17.5 Mt/yr indicated in Figure 3), and the erosion flux at 7 Mt/yr (compared to 8 Mt/yr indicated in Figure 3), indicating that the erosion flux accounts for about one-third of the anthropogenic flux. Figure 3 indicates that about 3/17.5 = 17% of the anthropogenic flux goes to the food supply. If one assumes that 17% of the erosion flux (1.2 Mt/hr) is routed back to the food supply by natural processes, the total P flux to the food supply would be 4.2 Mt/yr, leading to the estimate that about 3/4.2 or 71% of the P in our bodies originates from phosphate mining. It is likely higher than this figure because flood control activities prevent products of upland erosion, which are the natural source of soil fertility, from being distributed over downstream agricultural lands. The net effect of this cycle is the mining of phosphorus in concentrated locations, broad distribution over agricultural lands, shipping as food to urban areas, followed by discharge to landfills or water bodies (and eventually into the ocean). Along the way, significant losses occur from erosion of agricultural lands and runoff from improper land application of animal wastes. Natural ecosystems recycle phosphorus intensively, an estimated 46 times in terrestrial ecosystems, and 800 times in the oceans (Volk, 2003). However, our human systems pass much of the phosphorus through after a single use. If more phosphorus were recycled and conserved, less would need to be mined, and society would have more time to make any necessary adjustments.

ENVIRONMENTAL IMPACTS OF THE PHOSPHORUS CYCLE

The accelerated use of phosphorus, plus the lack of recycling compared to natural processes, results in much of the phosphorus being lost to the environment. The majority of this goes to surface waters. In freshwater lakes levels approaching or exceeding 0.5 mg, P/L are associated with cultural eutrophication, the excessive growth of algae and aquatic plants. In the short term, this can greatly increase the turbidity of the water. In a little-appreciated impact of eutrophication, depletion of carbon dioxide by photosynthesis can produce wide swings in pH. For example, if all the carbonate is removed from water with an alkalinity of 100 mg/L as $CaCO_3$, so that only hydroxide alkalinity remains, the pH would be 11.3! This could produce direct effects on aquatic life, as well as increasing the dissolution of heavy metals and converting ammonium to the more toxic ammonia. After the growing season, when the plants and algae die, they decompose and may deplete the water of oxygen, killing fish and other organisms. In slow-moving water bodies such as lakes, much of the phosphorus may find its way to the sediment. There, it participates in a complex series of reactions that may ultimately return it to the water column in the next growing season, again stimulating the eutrophication problems. Water quality models such as QUAL2K include this behavior, called “internal loading,” but do not incorporate the storage of sedimentary phosphorus. Thus, they do not predict the long-term effect of reductions in external loading of phosphorus on the internal loading, thereby underestimating long-term water quality improvements that would result.

Ultimately, much of the phosphorus from our food supply that doesn’t wind up in landfills (as some of the animal and human waste does) washes out to the ocean. There, together with nitrogen runoff, it can contribute to marine eutrophication, resulting in so-called ‘dead zones.’ These are coastal areas in which tens of meters thickness of bottom waters becomes oxygen deficient. Such zones are found around the world, most commonly near the mouths of large river systems. For example, one of the largest in the world forms annually in the Gulf of Mexico near the discharge of the Mississippi River and covers thousands of square miles. This year’s Gulf of Mexico dead zone was measured at a near-record 7,772 square miles (Hogue, 2010). In the past, it was thought that while phosphorus was the limiting nutrient in aquatic systems, nitrogen tended to serve that function in marine environments. However, it is now becoming evident that both N and P contribute to marine algal blooms (Alexander et al, 2008).

On the other hand, phosphorus fertilization may produce a beneficial increase in biological productivity in the sea. When the High Aswan Dam was constructed on the Nile River in Egypt, the natural source of nutrients to the eastern Mediterranean Sea (and to the Nile delta farmland) was attenuated, and the sardine fishery in the area collapsed. Over time, increased agricultural fertilizer use and wastewater discharge replaced much of the natural nutrients, and the fishery recovered (Nixon, 2003).

NUTRIENT RECOVERY, NOT JUST REMOVAL

Domestic wastewater contains some 4 to 16 mg P/L (Metcalf & Eddy, 2003). This originates mostly from the 1.0 to 1.5 grams of P in our diet that passes through to our excreta. About two-thirds of that is in the urine and the remainder in fecal matter. Phosphorus in wastewater may also originate from its use in detergents, and from the 0.5 to 1.0 mg/L that some water utilities add for corrosion control (Schock and Sandvig, 2009), such as zinc orthophosphate or polyphosphates. Together these result in a total P load in the U.S. of 2.7 to 4.5 g/capita/day (Metcalf & Eddy, 2003). The use of garbage disposals in a community would divert nutrients from the solid waste stream to the wastewater. These nutrients could be recycled by measures such as household or community composting.

Conventional biological wastewater treatment removes about 15% of the influent phosphorus in primary treatment, and an additional 40% in the secondary (Beier et al, 2009). An additional 35% can be removed if the secondary incorporates enhanced biological phosphorus removal (EBPR), for a total of about 90% removal. Most of the phosphorus removed by conventional biological processes will be in the form of organic phosphorus and, in the case of the additional removal by EBPR, intracellular polyphosphate granules. Over half of the phosphate in the sludge will be liberated as inorganic orthophosphate by anaerobic digestion. Recycling of thickener overflow and filtrate or centrate from dewatering has been estimated to add 37% to the phosphorus loading at the head of the plant (Beier et al, 2009).

EBPR processes developed over the past several decades reliably produce effluent P concentrations below 1.0 mg/L, and below 0.03 mg/L if combined with tertiary filtration (Barnard, 2009). This produces an increase in the phosphorus concentration in the biosolids byproduct from levels of 1.5% to 3% (g P/g dry wt.) in conventional biological treatment to as much as 7% (Smil, 2000) in the EBPR process.

EBPR can facilitate recovery (Barnard, 2009), although it might not be used for that purpose. Unfortunately, much of the phosphorus already removed by wastewater treatment processes winds up in landfills instead of in beneficial uses. With standard treatment such as stabilization and drying, EBPR biosolids can be used as a fertilizer and soil amendment. Composting has been used to process biosolids for this purpose. However, this use needs to overcome issues with other types of contaminants that may be present in the biosolids, especially heavy metals.

This problem can be avoided by methods that recover phosphorus from sludge. One category of recovery processes that is getting significant attention lately is crystallization processes with anaerobic digester centrate/filtrate (Dirk, 2009). Anaerobic digestion liberates much of the phosphate into dissolved form along with ammonium. By dosing $MgCl_2$ or MgO with pH control in an upflow crystallization reactor, pellets of struvite ($MgNH_4PO_4$) can be produced. These can be used directly as a slow-release fertilizer. Other crystallization processes have been developed to produce calcium phosphate and other precipitates instead (Piekema and Giesen, 1991). This product can be used in conventional fertilizer manufacturing processes to produce phosphoric acid directly. Such processes have recovered as much as 40% of the influent phosphorus from a treatment plant.

Chemical precipitation with alum can reliably achieve effluent concentrations below 0.05 mg P/L (Strom, 2010). Ferric chloride is also used as a precipitant. Precipitation may also be used in combination with EBPR to achieve low effluent P concentrations. Furthermore, chemical precipitation can increase the sludge volume produced. Chemical precipitation is used in place of secondary treatment in polar regions such as the far north of Sweden mainly because of its suitability to cold climates. Nevertheless it produces a side benefit of a high degree of phosphorus removal. Phosphate can also be precipitated with lime or with calcium silicate hydrate compounds (Petzet and Cornel, 2009).

Phosphate can be recovered directly from wastewater by adsorption, followed by desorption and precipitation into nearly pure calcium phosphate (Midorikawa et al, 2008). Other novel adsorbents are under development, such as zinc-aluminum double-layered hydroxides (Cheng et al, 2009) and zirconium-ferrite (Kondo et al, 2009). Some are studying the use of modified natural organic matter as adsorbents, which would facilitate reuse as fertilizer/soil amendment. For example, Eberhart et al (2006) found that pretreating wood fiber with carboxymethyl cellulose, a nontoxic anionic polymer, significantly improved the adsorption capacity of wood fiber treated with iron salts. Wartelle and Marshall (2006) enhanced the adsorption capacity of corn stover by quarternization.

Another approach to phosphorus recovery from wastewater is by extracting the residual ash from biosolids incineration. This has been studied using sulfuric or hydrochloric acid leaching (Niewersch et al 2009, Dittrich et al, 2009) or by bioleaching with *Acidithiobacillus* species (Zimmerman and Dott 2009). A number of thermal processes for recovering phosphorus from ash have been developed in Germany (Hermann, 2009, Adam et al, 2009) in which ash is treated at 1000° Celsius with chlorine compounds. Heavy metals are removed as volatile metal chlorides and the product can be converted into fertilizer. Ash from biomass can be used directly as a fertilizer if the source does not have heavy metals, such as in the case of animal wastes (Eichler-Loebermann and Bachmann, 2009).

Phytoplankton processes can be used to recover nutrients, including phosphorus, nitrogen and sulfur, from animal waste. Odor can be a form of nutrient loss from such wastes (Wegner, 2000) as well as a nuisance. The process involves algal lagoons in which cyanobacteria are inhibited by the use of agitation. The process also recovers organic matter as a resource. Algal processes can also be used for biofuel production (Barnard, 2009).

Different tacks from recovery from wastewater or biosolids are the source-separation and ecosanitation approaches (Esrey, 1999). This avoids the issue of contamination in wastewater, although there is still some concern about excreted pharmaceuticals. Ecological sanitation, or “EcoSan,” is an approach to human waste disposal that attempts to keep the waste processing close to its source and to achieve zero discharge of the resulting products. Examples exist in numerous countries in Asia, Central and South America, and Africa. It may or may not involve source separation of wastes.

In source separation, the phosphorus-laden wastes are collected before being diluted in the waste stream. Urine diversion is a particularly good candidate for this because it has the majority of the phosphorus in human waste, and because, since it is normally sterile as it leaves the body, it poses much less of a sanitation problem than fecal matter does. The separation can be accomplished using urine diversion, or “no-mix” toilets (Esry, et al, 2001) or by the use of urinals. However, in developed countries this would face the problem that the current infrastructure does not support the requirement for a separate plumbing system and systems for storage, collection, transportation, centralized treatment, distribution and end use. Urine-diverting toilets face the further obstacle of acceptance by some males because they only function when used in the seated position. Thus it might be necessary to include urinals in residential homes.

Urine can be used directly as a fertilizer without treatment if it is diluted by a factor of five to 10, or without dilution if loading is limited. Or, nutrients can be removed from the urine by precipitation or adsorption processes and applied separately (Lind, et al 2000).

Fecal matter, of course, needs considerable treatment to destroy pathogens. One approach is the composting toilet. This technology actually would work better if the urine were not combined with fecal wastes, as the mixture would have an excessive amount of nitrogen relative to the carbon content. Other applicable treatment technologies at the local scale include waste stabilization ponds, floating aquatic weed ponds (such as water hyacinth ponds) or constructed wetlands). An advantage of using fecal material, besides the added nutrient recovery, is that stabilized organic material further improves soil properties, especially its ability to retain moisture and nutrients.

Unfortunately, phosphorus recovery from wastewater is often not inherently economical. The cost of operation may not be borne by the value of the fertilizer product. However, there may be indirect benefits for some treatment plants to remove phosphorus from recycle streams (Kuzma, 2010). Treatment plants that combine biological treatment with chemical precipitation can reduce their chemical requirement by removing phosphorus from the post digestion recycle stream. Also, some plants have problems with spontaneous precipitation of struvite in digesters or pipes, producing difficult operating and maintenance issues. Removal of phosphorus from recycle streams can control this.

CONSERVATION

Human waste contains only about 17% of the beneficiated phosphate rock produced. Most of this loss is due to agricultural runoff. There are a variety of conservation agriculture techniques to reduce this loss. For example, in 'no-till agriculture,' genetically modified crops are used that are resistant to herbicides. Then, chemical herbicides can be used to limit weed growth instead of tilling which increases erosion. Other conservation agricultural techniques include improved field leveling or contour farming, or precision timing or placement of fertilizer. About 57% of the phosphorus that makes its way to the food supply is lost as food waste between 'the harvest and the fork.' Food waste is an area of nutrient waste that has not yet garnered much attention.

REDUCING CONSUMPTION

Any steps that would reduce the demand for phosphorus at any stage in the phosphorus cycle would likely have an almost proportionate impact on production, thereby extending our supply. For example, if populations in developed countries could be influenced to reduce their meat consumption, this would only affect the small 17% of the total production that goes into food. However, that reduction would also ultimately produce a corresponding reduction in agricultural production, thus reducing erosion and other losses along the chain. Beef consumption is one of the worst offenders in this sense. It takes an estimated 31.7 kg of grain to produce one kg of edible beef (Smil, 2002). For pork the ratio is 10.7, and for chicken it's 4.2. So, even changing the kind of meat that is eaten could have a significant impact.

Some farmers continue to use more phosphorus fertilizer than is necessary. This increases the loss associated with the inevitable erosion. Japan, which must import all its phosphorus, applies 26.2 kg P per hectare, compared to 3.7 for other developed nations. This has been justified on the basis of that country's acidic volcanic soils reducing the bioavailability of phosphorus. However, there have been studies showing that reduced fertilization rates would not reduce crop yields. More research is needed to confirm this.

When phosphorus prices spiked in 2008, drinking water utilities were faced with cost and availability issues for the corrosion inhibitor they use. Since this use may add significantly to the wastewater treatment phosphorus load, it may be prudent to take a harder look at alternative ways to stabilize water. The tradeoff in this application is that the phosphate is added both to protect the drinking water infrastructure and to protect health by reducing dissolution of lead from plumbing materials.

Finally, the effect of population growth itself must be considered as the master variable in phosphorus demand. Food and fertilizer are, in economic parlance, "inelastic" quantities, meaning that consumers will be willing to pay more if they have to in order to maintain their diets. Thus any restriction in supply will produce large price increases. The problem in the medium term is not so much that the supply of phosphorus will "run out," but that it will demand more and more of our economic productivity.

In the long term, however, we may have to consider an economy that once again depends largely on the flux of phosphorus from natural erosion, together with the kind of intensive conservation and recycling that was practiced in traditional Chinese and Japanese agriculture. Not only were human and animal wastes carefully conserved, but phosphorus was "mined" from river sediments. In Edo-period Tokyo, as the demand for fresh seafood increased, hostilities broke out between fishing villages that supplied it and farming villages that demanded the marine products for fertilizer. (It is interesting that this would be an example of a man-made reversal of the flow of phosphorus from terrestrial to marine ecosystems. A natural example of this is the movement of anadromous fish such as salmon from the ocean to the headwaters, where they may feed bears, who in turn deposit their 'fertilizer' in the local woods.)

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CONCLUSIONS

If we were to base our planning on what we know for sure, then we would take alarm at the possibility that we may not have the phosphorus resources necessary to feed the population growth that is anticipated for this century. There are factors that may forestall the problem, but it would be difficult to maintain that our phosphorus economy is sustainable.

Because a fundamental role of engineers is to design, the most natural way for environmental engineers to be involved in resource issues such as phosphorus is in the development and implementation of recovery technologies. However, engineers also use their approaches to perform analysis to determine the technology or management needs just as we use stream models to determine load allocations and atmospheric dispersion models for exposure assessment.

Similarly, environmental engineers could become involved in determining what needs to be done to make our society sustainable with respect to our material resources. Environmental engineers possess the tools and the conceptual outlook to become involved in global resource issues such as this one. We are familiar with integrating multiple phenomena into a subsystem, and modeling multiple interacting subsystems to form systems. In this way, environmental engineers are equipped to take a truly holistic view of the world, a view that will be required for solving complex interacting problems.

For us, 'thinking outside the box' may mean to look beyond an examination of our impacts on the environment, and include the ways we depend upon it.

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Global Phosphorus Research Initiative, *http://www.Phosphorusfutures.net*

Florida Institute of Phosphate Research, *http://www.fipr.state.fl.us/index.html*

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